U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
BULLETIN [illegible]

HURRICANES OF THE WEST INDIES

Prepared under direction of WILLIS L. MOORE, Chief of Weather Bureau

BY

OLIVER L. FASSIG
Professor of Meteorology
United States Weather Bureau

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU, OFFICE OF THE CHIEF,
Washington, D. C., September 16, 1912.

The Honorable SECRETARY OF AGRICULTURE.

SIR: I have the honor to transmit herewith copy of the text of the bulletin on "Hurricanes of the West Indies" by Oliver L. Fassig, professor of meteorology, United States Weather Bureau, with the recommendation that it be printed as Bulletin X of the Weather Bureau.

Very respectfully, your obedient servant,

WILLIS L. MOORE,
Chief U. S. Weather Bureau.

Approved.
W. M. HAYS,
Acting Secretary.

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HURRICANES OF THE WEST INDIES.

By Oliver L. Fassig.

(Professor of Meteorology, United States Weather Bureau.)

Introduction.—The opening of the Panama Canal will bring about a radical change in the sailing routes established during centuries of international traffic and turn much of the tide of commerce of the Atlantic and the Pacific toward the Isthmus of Panama. The convergence of new routes to the Caribbean Sea and the Gulf of Mexico will necessitate the crossing of a wide area swept at intervals during several months of the year by the severest type of storm known to the mariner—namely, the West Indian hurricane.

The increase in the size and speed of vessels has removed many of the hardships of ocean travel, while the steady improvement of wireless communication is eliminating additional terrors of the sea. But with all of our modern improvements in the mode of travel, and with our increased knowledge of the laws of storms, there will always remain sufficient menace to life and property in a storm at sea to make the hurricane an object to be dreaded and to be avoided if possible.

The occurrence of these storms has been carefully chronicled for centuries, and detailed descriptions of the most destructive are to be found in many publications.[1]

In 1899 a chain of cable-reporting stations was established along the margin of the hurricane region by the Chief of the United States Weather Bureau, and all well developed storms occurring within the area have since been carefully reported and charted from day to day. The material thus collected offers a most favorable opportunity for an additional study of the development and progressive movement of these tropical storms.

The terms "hurricane," "typhoon," and "cyclone" are applied to the same type of storm. Having their origin and development in different geographical areas and under different physical conditions, they have individual characteristics, but they are the same in essential character. In modern exact parlance they are all "cyclones," or storms in which the surface winds blow toward a central area of low barometric pressure at angles varying between 0° and 90°. This broad definition includes not only the intense storms of the Indian Ocean and the Bay of Bengal, originally called "cyclones," the hurricanes of the West Indies, and the typhoons of the Pacific, but also the temperate-region storms usually referred to as "barometric depressions," "storm areas," or simply "lows," and the tornadoes of our central valleys, and waterspouts over the seas in all parts of the world. In all storms of this class the surface winds blow more or less spirally inward toward an area of minimum atmospheric pressure, then upward and outward at elevations varying with the extent and intensity of the storm. The term "hurricane" is restricted to cyclones which have their origin and field of action within well defined limits embracing the West Indies and neighboring waters of the North Atlantic. The storms occurring in tropical regions of the western Pacific are called "typhoons." In the Indian Ocean they

[1] A. Poëy.—Table Chronologique de Quatre Cents Cyclones. 49 p. 8°. Paris, 1862.

B. Viñes.—Cyclonic Circulation and the Translatory Movement of West India Hurricanes. Sp. Publ. U. S. Weather Bureau. 8°. Washington, D. C., 1898. 34 pp.

E. B. Garriott.—West Indian Hurricanes. Bull. H, U. S. Weather Bureau. 4°. Washington, D. C., 1900. 69 pp. 4 chs.

retain the name originally given them by the early English mariners, namely, cyclones. It is only in comparatively recent years that the term "cyclone" was given the broader and at the same time more technical definition to include all so called "revolving" storms. The temperate-region cyclone covers a greater area than the tropical variety, the diameter of a well-developed storm of the middle latitudes being over 1,000 miles, and occasionally covering more than half the area of the United States; the cyclone of the Tropics is generally not over 300 to 400 miles in cross section, but probably penetrates to a greater height into the atmosphere than the extra-tropical cyclone. Tropical storms are accompanied by a greater fall in the barometer, resulting in more destructive winds and heavier rainfall than in the temperate-region cyclone, where the barometer falls with a more uniform gradient from the edge of the storm to the center. In the tropical storm there is a moderate decrease in pressure to within 40 or 50 miles of the center, and then a rapid fall, which in exceptional cases may descend to 28 inches and even less. This steep-pressure gradient marks the area of the destructive winds and the excessively heavy rainfall which are characteristics of the tropical storm.

The difference in the general direction of progression of the tropical and the temperate-region cyclones is due to their respective latitudes, in each instance the storm movement being controlled by the general drift of the atmosphere over the region in which the storm occurs. Within the Tropics this drift is from east to west and in the more northern latitudes from west to east.

The most intense and dreaded of all cyclonic storms is the tornado of our central valleys. With a diameter of less than a mile, and frequently of but a few hundred feet, the difference in atmospheric pressure between the outer edge and the center of such storms may be as great as the fall of the barometer in the most intense hurricane or typhoon, resulting in a wind of almost irresistible power, in which the total energy of the larger cyclonic storm, covering hundreds of square miles, seems to be concentrated into an area of a few acres.

The tornado, the thunderstorm, the waterspout, and the squall are usually secondary developments within certain well-defined portions of larger cyclonic storms, and especially within those in which the central area of low pressure departs widely from the circular form, and becomes an elongated ellipse.

HURRICANE AREAS AND HURRICANE TRACKS.

The tropical cyclones, as defined in the preceding paragraphs, originate almost entirely within certain well-defined areas of the tropical zone, and after taking a west to northwest course, recurve and enter the eastward drift of the middle latitudes. The comparatively small areas in which these storms originate may be readily seen by consulting Plate XXV. While no fixed boundaries are drawn beyond which these storms never occur, the areas indicated on the chart include the origins of over 90 per cent of all storms of this class recorded in the past 35 years. The hurricane belt may be defined as extending from longitude 56° west to 90° west and from latitude 12° to 26° north; or, roughly, the area embracing the Caribbean Sea, the Gulf of Mexico, and the West India Islands. Within this area the points of origin are distributed with a fair degree of uniformity, although belts of varying frequency are clearly discernible. This is most sharply defined on Plate I, showing the individual tracks of all hurricanes occurring during the past 35 years. There is a well-marked main path of greatest frequency through the northern half of the Caribbean Sea, extending almost due east-west between the Windward Islands and Jamaica; taking a northwest course through the Yucatan Channel and across the western end of Cuba, the path recurves in the eastern portion of the Gulf of Mexico and crosses the Florida Peninsula into the North Atlantic, with a north to northeast trend. There is a secondary path, not so well defined, extending from the northern group of the Windward Islands in a west-northwest direction across the Bahama Islands and recurving east of Florida in the North Atlantic Ocean. Between these two paths lie the Greater Antilles—Cuba, Jamaica, Haiti, and Porto Rico. Of these islands Porto Rico and Haiti are comparatively free from the devastating winds near the hurricane centers; the western half of Cuba is crossed in the recurve of a large percentage of the storms of the Caribbean Sea, or those of the main branch referred to above. These two paths

coincide very closely with the two branches of the great equatorial current of the North Atlantic Ocean, the main stream of which passes through the Caribbean Sea and the Yucatan Channel into the Gulf of Mexico and out into the Atlantic again through the narrow channel between Havana and Key West. Here it meets the northern branch of the equatorial current, which is more in the nature of a wide surface drift of equatorial waters passing through the Bahama group of islands, forming later in its course the eastern portion of the Gulf Stream.

In an analysis of the storm paths shown on the accompanying charts, an average track has been determined for each month and for the entire hurricane season. The mean, or normal paths were obtained by plotting the average latitude of the storm centers for every 2° of longitude along their paths. They represent, therefore, the mean geographical paths of all hurricanes for their respective periods. The fact that they are average paths, and not actual storm paths, should be borne in mind in reading the following paragraphs, in order to avoid confusion.

The *normal track* for the entire season, as determined from 135 storm paths occurring during the 35 years from 1876 to 1910, resembles a parabola in form. The first branch extends in a direction west by north, between the parallels of 18° and 20° north latitude to the center of the hurricane area (20° north 73° west), then northwestward and north; recurving over central Florida, the trend is northeastward over the North Atlantic along the second branch of the parabola. The average tracks, as determined in the manner described, are shown in the accompanying charts. The geographical center of origin for the entire season is in latitude 20° north and longitude 73° west, or just off the northwest coast of Haiti. The average point of recurve is in latitude 28° north and longitude 82° west, or in the center of the Florida Peninsula. While the normal paths for the individual months of the hurricane season do not differ greatly from the normal track for the season, there are certain peculiarities which are worthy of further notice, especially the relation between the origin of the storm and the subsequent path followed. The path pursued by a hurricane depends to a large extent upon the point of origin. Those having their origin far to the east, as in August and September, are most likely to move west-northwest for a considerable distance along the first branch, recurve, and move northeastward, the path closely resembling the normal parabolic course. Those having their origin in the western waters of the Caribbean Sea have a tendency to move northwest or north along the recurve of the normal track, and then enter the second branch; or they may, in higher latitudes in the western portion of the hurricane area, immediately move northeastward along the second branch of the normal track. While the average hurricane track resembles a parabolic curve, some storms are found only in the first branch and do not recurve; others are formed in the recurve; while others again move only along the second branch. In other words, a hurricane may have its origin in any portion of the normal track, but for the balance of its existence will approximately follow the normal path for the month in which it occurs. An examination of the position of the origin of 134 hurricanes reveals the following: 82 were formed in the first branch, or 63 per cent; 22 were formed in the recurve, or 17 per cent; 28 were formed in the second branch, or 20 per cent. The variations in the average path of storms for the different months of the hurricane season, and variations in the points of origin, are shown in the following table:

Average paths and origins of hurricanes.

Month.	Origin.		Recurve.		Second branch, first day.		Number of storms.	Origin in—		
								First branch.	Recurve.	Second branch.
	N. lat.	*W. long.*	*N. lat.*	*W. long.*	*N. lat.*	*W. long.*		*Per cent.*	*Per cent.*	*Per cent.*
June and July	20	80	28	87	29	82	13	55	29	16
August	20	70	30	83	33	79	32	88	6	6
September	20	71	28	81	30	80	45	69	20	11
October	22	76	25	80	29	78	40	40	17	43
Mean, May–November	20	73	28	82	30	79		63	17	20

The advance of the season is marked by a slight increase in the latitude of the point of recurve. Reference to the charts will show that the mean track for June and July storms recurves in latitude 28° north. The August storms recurve at the highest point reached during the season, namely, 30° north. From August there is a gradual retreat of the point of recurve, September storms recurving in latitude 28° north and October storms in latitude 25° north. The movement of hurricane paths from south to north and return southward coincides very closely with the movement of the trades and the equatorial belt of calms. It will be noted in the above table that the latitude of the *point of origin* varies only between 20° and 22° north latitude during the season; that in longitude the limits of variation are 70° and 80° west, the storms of the early part of the season, June and July, forming far to the westward of those of August and September, while those of October form in the intermediate region. The *point of recurve* varies from 25° north latitude in October to 30° in August, with a comparatively small variation in longitude. The figures in the table also show some interesting facts concerning the distribution of the points of origin with the advance of the season. For instance, during August the origin of the storm is in the first branch of the normal track for the season in 88 per cent of all August storms, and in the recurve and second branch but 12 per cent; in October the origin occurs in the first branch in 40 per cent of the storms and in the recurve and second branch in 60 per cent.

The more important characteristics of these tropical storms are pointed out in the following paragraphs, for each month of the hurricane season.

June and July hurricanes (*see Pl. II*).—June and July storms are comparatively infrequent, only 13 having occurred in the past 35 years; of these, 8 occurred in June and 5 in July. All of the June storms, and all but one of the July storms, originated within the area bounded by the meridians of 72° and 90° west longitude, and the parallels of 15° and 26° north latitude; that is, in the western half of the hurricane area, and more particularly in the Caribbean Sea south of Cuba and immediately east of the Yucatan Peninsula. The paths pursued led, in nearly all cases, northwest or north, or within the recurve of the normal hurricane track. In only one instance did a storm of this period arise as far eastward as the Windward Islands, namely, that of July 20–27, 1887. This storm resembled very closely the August storms in point of origin and in the path followed. Of the 13 storms of June and July, four failed to recurve within the Tropics, two of these passing up the Mississippi Valley and two disappearing in the Gulf of Mexico. The majority of these storms passed through the Yucatan Channel, crossed the eastern Gulf of Mexico in a northerly direction and continued northeastward across Florida. The western end of Cuba was also within the influence of these storms, and one crossed Haiti. Porto Rico has been entirely outside of the area of June and July storms during the past 35 years. Only a little over half of these storms (55 per cent) had their origin in the first branch.

August hurricanes (*see Pl. III*).—During the month of August the origins of hurricanes are shifted from the western half of the hurricane area to the eastern. Most of the origins during this month are east of Cuba—between the meridians of 56° and 75° west longitude, and between the parallels of 12° and 25° north latitude. They pursue a comparatively long path in the first branch, at first almost due west, then west-northwest and northwest, and recurve in a higher latitude than the earlier and later storms. The mean track during August closely follows the parallel of 18° north latitude from the Windward Islands to Haiti, then takes a direction more nearly northwest to the southern end of Florida and recurves along the west coast of Florida. Many of the August storms cross the Gulf of Mexico in a northwest direction and fail to recurve, but pass over the mainland of Mexico or across our southwestern States. As stated above, 88 per cent of all August storms had their origin in the first branch of the normal track, 6 per cent in the recurve, and 6 per cent in the second branch. These storms occasionally originate far to the eastward of the Windward Islands; a notable instance is the hurricane of August 14–31, 1873, which formed the subject of careful study by Capt. Toynbee of the British Navy. (See Pl. VIII.) The August storms are those most probable in Porto Rico, although fortunately of infrequent occurrence over the island in the past.

September hurricanes (see Pl. IV).—The September storms (like those of August) have their origins very largely well toward the eastern end of the hurricane area, but there is a noticeably greater uniformity of distribution of origins through the entire area. They also have a comparatively long first branch. They take a west-northwest course. The average point of recurve is along the eastern coast of Florida in latitude 28° north. Only a small percentage of these storms fail to recurve, but many enter the Southern States before recurving. Sixty-nine per cent of the September storms had their origins in the first branch, 20 per cent in the recurve, and 11 per cent in the second branch. The August and September hurricanes extend farther across the Gulf of Mexico than those of June, July, and October. The latitude of the point of recurve of September storms is the same as that for June and July storms, although the recurve of the September storms is somewhat farther to the east.

Next to August, September is the most probable month for hurricanes in Porto Rico.

October hurricanes (see Pl. V).—A striking feature of the October storms is the convergence of tracks toward the Yucatan Channel and the western end of Cuba. The area of recurve is restricted to a comparatively narrow belt between the meridians of 75° and 85° west longitude, the storms crossing the western end of Cuba and the Florida Peninsula in the recurve. Only 40 per cent of the October storms originated in the first branch of the normal track; 17 per cent had their origins in the recurve and 43 per cent in the second branch. The point of recurve during October is farther south than during any other month of the hurricane season—namely, 25° north latitude.

Variations in the average annual path of hurricanes.—Determining the mean path of hurricanes for each year and charting the results, we find that there is considerable variation in the latitude and longitude of these annual paths. For certain years the paths will be found far to the west of the normal hurricane track. The variation in latitude is not so great, but still considerable. In 1891 the mean path was as far east as 67° 30′ west, and in 1886 as far west as 83° 15′ west. (See Plate VI.) Further investigation of this point will probably reveal a close relationship existing between the paths of these storms and the distribution of pressure over the North Atlantic.

FREQUENCY OF HURRICANES.

Conditions favorable for the formation of hurricanes in the West Indies begin in the month of June, but do not become well developed until the month of August. From August to the close of October is the real period for these storms, as is shown by the following figures of frequency during a period of 35 years:

	May.	June.	July.	August.	September.	October.	November.	Season.
Frequency	1	8	5	33	43	42	2	134
Per cent	1	6	4	25	32	31	1	....

The abrupt increase in the frequency in August and the almost complete cessation at the close of October are remarkable features of the seasonal distribution of these storms. The above figures show that 88 per cent of all hurricanes recorded during the past 35 years occurred during the months of August, September, and October, leaving but 12 per cent for the remainder of the season. The active season does not really begin until the second decade of August, and is then maintained until near the close of October, covering in all about 10 weeks. (See Plates VII and VIII.) The relative frequency for the months has varied considerably in the period under consideration. The distribution for the period extending from 1876 to 1900 is here compared with the longer period from 1876 to 1910 for the months of August to October. The relatively great increase in the number of September storms during the decade just closed is very marked. The recording of storm frequency, however, is largely a matter of individual judgment. Not all storms of the Tropics can justly be classed as hurricanes, and the available information is at times too meager for the exact determination of the path and intensity of the disturbance,

thus giving rise to differences in judgment. For example, the records of the United States Weather Bureau show 11 storms of hurricane force in the year 1886, while the late Rev. Viñes, director of the Havana Observatory, refers to 20 storms in the same year, a figure which doubtless includes some minor disturbances. The distribution through the season and from year to year, based upon the records of the United States Weather Bureau, is shown in Table IV. The annual frequency has varied from a total absence to a maximum of 11 hurricanes. The years which were free from storms were 1877, 1897, and 1905; there was but 1 hurricane in each of the years 1876, 1890, 1896, 1902, and 1911. In the years 1886, 1887, 1888, 1889, 1891, 1901, 1906, and 1909 the storm frequency varied from 6 to 11, the maximum of 11 occurring in the years 1886 and 1887. In 1886 2 storms were recorded in each of the months June, July, September, and October, and 3 in August. The average frequency for the entire hurricane season is 4 storms, with a distribution through the season of 1 storm for each of the months of August, September, and October, in round numbers, leaving 1 for the remainder of the season.

PROGRESSIVE MOVEMENT OF HURRICANES.

Tropical storms move much more slowly than storms of the middle and higher latitudes. This is a decided practical advantage to the forecaster, as it enables him to give a more timely warning of the approach of hurricanes after the point of origin and the initial progress of the storm have been determined. The average velocity of the temperate-region cyclone in the United States is about 700 miles per day, or about 30 miles per hour, whereas the average velocity of hurricanes and other tropical storms is approximately but 300 miles per day, or 12.5 miles per hour. While individual storms show large departures from the mean velocity, the variations are less in tropical storms than in those of the higher latitudes; the greater uniformity in the case of the tropical storms doubtless finds an explanation in a greater uniformity in the general drift of the atmosphere within which the storms are formed and carried forward. The progressive movement of 135 hurricanes of the West Indies has been determined for each day throughout the entire course of the storm within the tropical zone. The detailed results are shown in Table III. The average rate of movement in the first branch, the recurve, and in the second branch is shown in the following table for each hurricane month and for the entire season:

Mean daily movement of hurricanes.

[In miles per day.]

	Number of storms.	First branch.					Recurve.	Second branch.		
		First day.	Second day.	Third day.	Fourth day.	Fifth day.		First day.	Second day.	Third day.
May to July	14	290	260	200	308	400	286	340	325	150
August	33	341	280	244	236	234	257	383	356	200
September	49	282	246	251	265	196	250	408	495	404
October	40	231	232	181	255	275	247	404	428	497
Season	136	286	254	219	266	276	260	384	403	....
		260						392		

The mean daily movement of hurricanes for the entire season is about 300 miles, or 12.5 miles per hour. In the first branch and the recurve the mean velocity is 260 miles per day, or 11 miles per hour, and during the first two days of the second branch 392 miles per day, or 16 miles per hour. These figures are not in accord with the frequently published statement that hurricanes move more slowly in the recurve than in the first branch. While the average rate of movement, based upon an analysis of storms for the entire season, is shown to be about the same in the first branch and the recurve, it frequently happens that the storm does move more slowly in the recurve. In fact, the storm center is at times nearly stationary for two or three days, the further progress being impeded by the presence or formation of an area of high baro-

metric pressure in the path of the storm. A noteworthy instance of such a condition may be seen in the path of the storm of October 14–20, 1910. (See Plate V.) The center of this storm apparently moved in a small circle, remaining in nearly the same position between Havana and Key West for five successive days.

The velocity of progression of the storm along the first branch is in harmony with the average velocity of the westward drift of the atmosphere near the surface of the earth in the portion of the trade-wind belt in which these tropical storms occur. As the storms move northward into the eastward drift of the middle latitudes the mean velocity increases, especially in the months of September and October.

There is no apparent increase in the velocity of the storm as it moves westward along the first branch. The average rate of movement for the entire season during the first five days of progress along the first branch is shown in the following figures:

Daily movement in the first branch.

	Miles per day.
First day	286
Second day	254
Third day	219
Fourth day	266
Fifth day	276

The mean for the five days is 260 miles, or 11 miles per hour. The mean rate of movement in the first branch, the recurve, and the second branch is summarized for the months and the season in the following table:

Mean rate of movement.

[In miles per hour.]

	First branch.	Recurve.	Second branch.
May to July	12	12	14
August	11	11	15
September	10	10	19
October	10	10	17
Mean for the season	11	11	16

The most conspicuous feature of the above figures is the rapid increase in the velocity from 10 miles in the first branch and the recurve to 18 miles in the second branch in the September and October storms, while there is little or no increase in the storms of May to August. This fact is doubtless explained by the greater velocity of the general drift of the atmosphere in the higher latitudes with the passing of the summer months. (See Table III.)

DURATION AND INTENSITY OF HURRICANES.

Duration.—The period of duration of hurricanes while within the zone below the latitude of about 30° N. varies considerably for the individual storms. The average duration is about 6 days, with extreme limits of 1 day and 19 days. The values for the individual months are shown in the following statement:

Duration of hurricanes within the Tropics.

	Total number of storms.	Duration in days.		
		Longest.	Shortest.	Mean.
June	8	6	3	4.1
July	5	9	2	5.4
August	32	10	2	5.4
September	45	19	1	6.2
October	40	12	2	5.7
Season	130	....	....	5.8

About 3 days are spent in moving westward along the storm's path and two days in the recurve. After the recurve the storm soon enters into the region of temperate zone cyclones and may continue its existence for many days, sometimes crossing the entire expanse of the North Atlantic and even into Europe. The length of time spent in the first branch and recurve varies somewhat with the progress of the season. Storms of the early part of the season, June and July, and of the late season, October, occupy about 3 days in the first branch, while those of August and September move westward for an average of 4 days before recurving. The variation in the duration of the storms in the first branch and recurve may be seen in the following tables. A considerable number of all hurricanes reach the latitude of temperate-region cyclones before the recurve is completed.

Duration of hurricanes in the first branch.

Duration.	Number of storms in—					
	June and July.	August.	September.	October.	Season.	
						Per cent.
1 day	3	5	7	....	15	17
2 days	2	3	8	8	21	24
3 days	1	7	7	1	16	20
4 days	1	1	2	3	7	9
5 days	2	2	2	1	7	8
6 days	....	7	5	1	13	15
7 days	....	1	2	1	4	5
8 days	....	....	1	....	1	1
9 days	....	....	1	....	1	1
Number of storms	9	26	35	15	85	....
Average duration	3	4	4	3	3 days.	

Duration of hurricanes in the recurve.

Duration.	Number of storms in—					
	June and July.	August.	September.	October.	Season.	
						Per cent.
1 day	1	6	11	8	26	27
2 days	8	12	15	11	46	47
3 days	....	1	10	4	15	16
4 days	....	1	2	2	5	5
5 days	....	....	2	1	3	3
6 days	....	1	1	....	2	2
Total number of storms	9	21	41	26	97	....
Average duration in days	2	2	2	2	2	....

Intensity of tropical storms.—It is not an easy matter to secure sufficient data of a reliable nature upon which to base a statement as to the relative intensity of tropical storms along the path of the storm. They pass mostly over water areas where there are relatively few observers, and it is only occasionally that a ship happens to pass through the center of a storm or the observer is in a position to make an accurate report on the velocity of the wind and the amount of rainfall or to furnish data of value for a comparative study of the intensity of the storm at different points along its path. In most cases it is necessary to draw conclusions from conditions at a considerable distance from the center of the storm. Storms do not seem to show a progressive increase in intensity as a rule after they have become fully developed, although it frequently happens that any obstacle encountered along the path, generally in the form of an area of high pressure or a rising barometer, will increase the violence of the storm. After the recurve, and as the area of the storm increases, the fury of the storm seems to subside. The

diagrams on Plate IX reproduce the barograms, or tracings of the barometer, during several well-known tropical cyclones, from which the relative intensity of these storms may be judged, as the violence of the storm generally varies directly with the depression of the barometer. The island of Porto Rico was directly in the path of the hurricane of August 7–20, 1899. As this storm was one of the most destructive experienced in the history of the island, both as to loss of life and property, and as it was a typical West Indian hurricane, occurring in the height of the hurricane season, a subsequent chapter is devoted to the history of its development and progress.

HURRICANES, CYCLONES, AND TYPHOONS.

The essential similarity in the structure and intensity of these tropical storms has already been referred to. They are formed under similar conditions and move in similar paths, although in widely separated areas, within the tropical zone. West Indian hurricanes and East Indian cyclones are almost entirely confined to the warm months of the year, and the typhoons, although occurring throughout the year, are comparatively feeble and infrequent during the winter months. The relative frequency of these storms, as well as their distribution through the season, is indicated in the following tables, showing the number of each recorded in the stated period:

Relative frequency of hurricanes, cyclones, and typhoons (1880–1899, 20 years).

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Cyclones (Bay of Bengal)	....	....	....	....	9	26	37	25	38	26	16	7	184
Typhoons (Western Pacific)	6	....	3	10	25	36	70	66	83	56	44	19	418
Hurricanes (West Indies)	....	....	....	....	1	3	3	25	24	27	1	2	86
Total frequency	6	....	3	10	35	65	110	116	145	109	61	28	688
Mean monthly frequency	(1)	....	(1)	1	2	3	6	6	7	5	3	1	34
Percentage of total frequency	1	(1)	(1)	2	5	10	16	17	21	16	9	4	100

[1] Occasional.

These figures show a great variation in the frequency of tropical storms, the totals for a 20-year period being 418 typhoons and cyclones of the Far East, 184 cyclones of the Bay of Bengal, and only 86 hurricanes of the West Indies. The difference in the length of the active storm period (more than one storm per month) is also quite marked: For typhoons, from May to November or 7 months; for cyclones, from June to October or 5 months; for hurricanes, from August to October or 3 months. Combining these figures representing monthly frequency, we have a fairly reliable estimate of the annual storm frequency for the entire tropical zone in the following figures:

Mean monthly frequency of tropical storms.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Average frequency	(1)	(1)	(1)	(1)	2	3	6	6	7	5	3	1	34

[1] Occasional.

Further details concerning the frequency of tropical storms will be found in the tables of the appendix, and in Plates X and XI.

As before stated, hurricanes are confined to West Indian waters and islands and to the adjacent land areas to the west and north, namely, the coasts of Central America and Mexico and the Gulf and South Atlantic States. The East Indian cyclones are confined mostly to the Bay of Bengal; while the typhoons of the Far East occur in the China Sea, the Philippines, and within an area over the Pacific Ocean extending for 1,000 miles eastward of the Philippines. Plate XV suggests a possible close connection between the Bay of Bengal cyclones and the typhoons of the Far East. The paths of two storms, occurring in October of 1891 and 1897, respectively, are traced almost continuously from the typhoon area into the Bay of Bengal; the doubtful portion of the path is probably due to lack of reports.

The areas within which these tropical storms originate may be defined with considerable accuracy by the following limitating parallels of latitude and meridians of longitude:

	Latitude.	Longitude.
Hurricanes of the West Indies	12° 28° N.	55° 95° W.
Cyclones of the Bay of Bengal	8° 22° N.	100° 80° E.
Typhoons of the western Pacific	5° 20° N.	150° 115° E.

Fully 95 per cent of the tropical storms recorded within the past thirty years have had their origins within the areas defined above. (See Pl. XXV.) Special attention is directed to the charts showing the distribution of the points of origin of tropical storms. Hurricanes and typhoons show a fairly uniform distribution within their respective storm areas, but the Bay of Bengal cyclones show a remarkable increase in the frequency of origins toward the head of the Bay. The same boundaries will apply fairly well to the entire paths of these storms, with the exception of the northern boundary line. After recurving they take a course toward the north and northeast, entering into the eastward drift of the higher latitudes and following the paths of temperate-region storms. The paths of individual storms and the mean paths for a series of years are shown in the accompanying charts, also the points of origin of the storms and the relative frequency of occurrence. Especial attention is invited to the chart of the world showing the relative position of these storm areas of the Tropics and the distribution of pressure over the Northern and Southern Hemispheres (Pl. XXV). It is highly probable that the movements of the areas of high pressure shown upon the chart are a direct agency in the formation of the larger cyclonic storms. This statement is given further consideration in the section on the theory of tropical storms. (See Pls. XI–XV.)

SIGNS OF AN APPROACHING TROPICAL CYCLONE.

The diurnal changes in pressure, wind direction, and cloud conditions in the Tropics are so uniform that any departure from the normal is a signal for greater caution in noting the atmospheric conditions, especially during the period from July to October, when certain areas are subject to storms of the greatest violence. A slight fall in the barometer, especially during the months of August and September, in Porto Rico, for example, an east wind increasing in force and not in accord with the usual diurnal variation in direction and force, an increase in the extent and variety of clouds, and other signs which the observant resident quickly notes, give rise to general apprehension and alarm, and the local offices of the Weather Bureau are soon besieged by applicants for further information. In general the atmospheric changes experienced in the Tropics upon the approach of a storm do not differ greatly from those of more northern latitudes. The feeling of personal discomfort which arises from increased humidity and diminished wind movement, the falling barometer, increasing cloudiness, the formation of halos, and changes in wind and cloud direction and velocity, are common to all parts of the world upon the approach of a general cyclonic disturbance. There are, however, certain cloud effects and atmospheric conditions which have a greater significance in the Tropics than in more northern latitudes as premonitory signs of an approaching storm. First in point of time and in importance in the Tropics are the cirrus clouds; the white fleecy cloud-forms which float at great elevations above the earth's surface and take on forms and motions over an atmospheric disturbance distinctly different from those observed at times of normal conditions of the atmosphere.

Among those who have contributed most to our knowledge of cloud forms and cloud movements in connection with West Indian hurricanes must be named the late Rev. Benito Viñes, for many years director of the Havana Observatory, in Cuba. As a result of many years of close observation of cloud forms and air currents associated with the origin and progressive movement of West Indian hurricanes, Padre Viñes formulated the following law of cyclonic currents:

In the West Indian cyclones the rotation and the cyclonic circulation take place in such a manner that the inferior currents, as a rule, converge more or less toward the vortex; at a certain altitude the currents follow a nearly circular course, and higher still their course is divergent. It is particularly to be noticed that this divergence is all the greater as the currents occupy higher altitudes, until a point is reached where the highest cirrus clouds are seen to move in completely divergent radial direction. Thus, if the vortex lie due south the wind will blow more or less from the east-northeast, the lowest clouds will move from the east, the alto-cumulus clouds from the east-southeast, the dense cirro-stratus from the southeast, the cirro-cumulus from the south-southeast, and the light cirrus from the south. * * * To sum up briefly, we find the cyclonic currents which exhibit the greatest regularity and point out best the bearing of the vortex are those of the cirrus and the low clouds. The current of the cirrus clouds is that which should be selected in preference when the first indications of the approach of a cyclone are seen and the vortex is still far distant. In the interior of the storm the observer must be guided principally by the movements of the low clouds.

This law of Viñes, while not applicable in all cases, is of great assistance in determining the direction of approach and the probable intensity of hurricanes in the West Indies. The character of the cirrus and cirro-stratus and their value as storm warnings are well described by Rev. F. Faura.[1]

The best means for determining the center [of a storm] and for following up its movements are the observations of cirri, little clouds of a very fine structure and clear opal color, which appear as elongated feathers, and which are known among sailors as "cocktails." * * * Long before the least sign of bad weather is noticeable and in many cases when the barometer is still very high, being under the influence of a center of high pressure, which generally precedes a tempest, these small isolated clouds appear in the upper regions of the atmosphere. They seem to be piled up on the blue vault of heaven and drawn out in the direction of some point on the horizon toward which they converge. The first to present themselves are few in number, but well defined and of the most delicate structure, appearing like filaments bound together, but whose visibility is lost before they reach the point of radiation. We often had an opportunity to watch them at the observatory of Manila, when the center was still 600 miles distant. The best times for observing the cirri are sunrise and sunset. If the sun is in the east and very near the horizon, the first clouds which are tinged by the solar rays are the cirro-strati which precede the cyclone, and they are also the last to disappear at sunset, inasmuch as they overspread the horizon. Such times are the best for determining the radiant point of the cloud streaks, and at the same time for ascertaining the direction in which the center lies. Later on the delicacy of form, which characterizes this class of clouds in its earlier stages, is lost, and the clouds appear in more confused and tangled forms, like streamers of feather work, with central nuclei, which still maintain this direction, so that the point of radiation can still be detected. In order to ascertain approximately the direction in which the center is advancing in its movement of translation, it is necessary to determine the changes of the radiant point at equal intervals of time and to compare them with the movements of the barometer. If the point of convergence does not perceptibly change its position, but remains fixed and immovable for a long time, even for several consecutive days, it is almost certain that the tempest will break over the position of the observer. In this case the barometer begins to fall shortly after the first cirrus clouds have been observed and sometimes even before. At first it falls slowly, without completely losing the diurnal and nocturnal oscillatory movements, but changing somewhat the hours of maximum and minimum. The daily reading is observed to be each day less than that of the preceding day. That part of the horizon in the direction of the storm begins to be covered by a cirrus veil, which increases slowly until it forms an almost homogeneous covering of the sky. This veil is known by the name "cirro-pallium" of Poëy, and is that which causes the solar and lunar halos, which are never absent when a storm approaches. Beneath the veil a few isolated clouds, commonly called "cotton," appear. They are much more numerous and larger on the side lying toward the storm where they soon appear as a compact mass. At such times the sunrises and sunsets are characterized by the high red tint which the clouds assume, resembling a great fire, especially in the direction of the cyclone. The wind remains fixed at one point, showing only a few variations, which are due principally to the squalls which continually exert their force within the limits of the storm. The low or "cotton" clouds successively and from time to time cover the sky, throwing out occasional squalls of rain and wind, but, the squalls having passed, a lull ensues, the cirrus veil remaining, and likewise the hurricane bank of clouds, which seems fixed to the same spot in the direction of the storm. This state of the atmosphere continues until the bank of clouds invades the point of observation, in which case the squalls will be continuous and the wind will increase in violence each moment.

A brilliant display of color at sunset frequently accompanies these higher fleecy clouds, but similar color effects also appear during times of local disturbances, such as thunderstorms, when the upper portions of the "thunderheads" and the false cirrus clouds above them produce quite as gorgeous a display of color as do the cirrus preceding a hurricane. The colors do not invariably precede a hurricane, while they are frequently seen in the cirrus clouds during times of normal atmospheric conditions; however, a brilliant cloud coloring may be a valuable precursory sign when taken in connection with other indications.

[1] F. Faura, (S. J.)—"Señales precursoras de temporal en el archipelago filipino." See: José Algué. The Cyclones of the Far East. 4° Manila, 1904, p. 103.

Squalls and showers as precursory signs.—A more reliable warning of the proximity of a typical cyclone is an unsettled and squally condition of the weather. It rarely happens that showers and squalls are not experienced from 24 to 48 hours in advance of the storm proper. The following paragraphs from Eliot's excellent Handbook of Cyclonic Storms in the Bay of Bengal[1] concerning the relation between squalls and cyclones, while based upon a study of a particular area, are quite as applicable to hurricanes of the North Atlantic and typhoons of the Pacific:

It should be kept carefully in view by mariners of the Bay of Bengal that the formation of a cyclonic storm is a gradual process, and that it is only when the disturbance has passed beyond the initial stages that it becomes a storm in the proper sense of the word. The formation of a large storm is due to the prolonged continuance of actions, processes, and changes of the same kind as those that are occurring in the atmosphere at all times when rain is falling and strongish humid winds are blowing. Whatever the causes and origin of cyclones may be, the history of all cyclones in the Bay of Bengal shows that they are invariably preceded for longer or shorter periods by unsettled, squally weather, and that during this period the air over a considerable portion of the bay is gradually given a rapid rotary motion about a definite center. During the preliminary period of change from slightly unsettled and threatening weather to the formation of a storm, more or less dangerous to shipping, one of the most important and striking points is the increase in the number and strength of the squalls, which are an invariable feature in cyclonic storms from the very earliest stages. First of all, the squalls are comparatively light and are separated by longish intervals of fine weather and light variable or steady winds, according to the time of year. They become more frequent and come down more fiercely and strongly with the gradual development of the storm.

The area of unsettled and squally weather also extends in all directions, and usually most slowly to the north and west. If the unsettled weather advances beyond this stage (which it does not necessarily do), it is shown most clearly by the wind directions over the area of squalls. The winds always settle down into those which invariably occur over an area of barometric depression or cyclonic circulation, or, in other words, are changed into the cyclonic winds of indraught to a central area of low barometer and heavy rain. As soon as the wind directions indicate that a definite center of wind convergence has been formed in the bay, it is also found that the center never remains in the same position for any considerable interval of time, but that it moves or advances in some direction between northeast and west with velocities which not only differ very considerably in different storms but also at different stages of the same storm.

This preliminary period of unsettled, squally weather may extend over several days, or may last only a few hours. It is of course impossible to determine exactly the hour at which the change from the antecedent disturbed, squally weather to the cyclonic storm takes place. * * * These squalls are at first of short duration and comparatively feeble, but as they increase rapidly in frequency and intensity they are an almost certain indication of the commencement or of the existence of a cyclonic storm, and they become more and more prominent and more frequent and severe during the birth and growth of the cyclonic storm. It should, however, be carefully noted that squalls more or less severe occur under several sets of conditions, and it is hence desirable to discriminate between these. This is the more necessary in order that it may be fully realized that whilst squally weather is a necessary antecedent in time to a commencement of a cyclonic storm, squally weather is not necessarily followed by a cyclonic storm.

Thunderstorms.—Thunderstorms can not be considered as precursory signs, although they generally occur in connection with tropical cyclones, as the storm is well under way before thunder is heard. Viñes[2] and other students of tropical storms regard them as evidences of the breaking away of the storm:

The absence of electrical discharges within the cyclone is a phenomenon so constantly observed that whenever during a tempest the rolling of thunder is heard or flashes of lightning are perceived this is considered as a favorable sign indicating the speedy disappearance of the storm. Especially among the country folks this opinion is general and deeply rooted. The crashing of thunder and the crowing of the cock are here the barometer of the farmer during cyclones, a barometer which, as he affirms, never deceives him. As long as the rooster does not crow, nor is there heard any peal of thunder, the storm will continue to rage in full force. But as soon as the lively crowing of the cock or the pealing of the thunder reaches his ear, the tempest, to his conviction, is about to pass away.

Ocean swells.—As a result of the diminished pressure and the high winds near the center of a cyclone, as it passes over the sea, waves are propagated in all directions. The direction from which the resulting swell is experienced points out the bearing of the center of the storm with a considerable degree of accuracy. The ocean swell may therefore, and often does, announce the approach or the passing of a storm many hours and sometimes two or three days in advance of the center.

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[1] J. Eliot; 2d ed. 8° Calcutta, 1900–1901.

[2] B. Viñes (S. J.)—Apuntos sobre los huracanes de las Antillas. Habana, 1877, p. 190.

The fall of the barometer.—The premonitory signs enumerated above are the most important features of the weather conditions preceding the storm area proper, and are generally observed at distances varying from 500 to 1,000 miles in advance of the center of a storm. Within the radius of a day's movement of the storm, or, roughly, from 300 to 400 miles from the center, other and more reliable signs become evident to the observer accustomed to the regular sequence of weather changes in the Tropics. The barometer begins to fall slowly but steadily, although the diurnal variation is still well marked; the wind begins to increase in force, obliterating normal diurnal changes, and backs to the east or northeast, if the observer is directly in the path of the storm, or changes from northeast to north and northwest if the path of the center of the storm lies north of the observer. At the same time the direction and velocity of the lower clouds show unmistakable evidence of the presence of a storm and the bearing of the center. When the storm center is still far distant the phenomenon called the "bar of the cyclone" may frequently be seen. This is a dense mass of rain cloud formed about the center of the storm, giving the appearance of a huge bank of black clouds resting upon the horizon, which may retain its form unchanged for hours. It is usually most conspicuous about sunrise or sunset. When it is possible to observe this bar, the changes in its position at intervals of a few hours will enable the observer to determine the direction of movement of the storm.

While any one of the signs above enumerated may fail to be observed or may turn out to be a false alarm, the combination of several or of all of them may be trusted to give ample warning of the existence of a well-developed storm in the vicinity of the observer. The problem then becomes one of determining the bearing of the center and the probable intensity of the storm. The mariner, who is still dependent upon his own observations, is naturally a trained observer, and sufficiently weather wise to keep out of the way of the center of a cyclone. Fortunately the efficient organization of the national weather services, and the ability to distribute information rapidly and widely by means of the telegraph and by wireless messages, make it unnecessary to rely upon the local prophet to give warning of the approach of a storm. The problem then for the mariner is to get out of the way and for the landsman to do the best he can in the way of preparing for the storm.

THE HURRICANE OF AUGUST 7–20, 1899.

On the 8th of August, 1899, one of the most destructive storms in the history of Porto Rico passed directly across the entire length of the island. More than 3,000 lives were lost, mostly from drowning; the high winds and heavy rain completely destroyed a maturing coffee crop valued at over $7,000,000; the plants of the banana and plantain, which furnish the principal food supply of the mountain people, were mostly uprooted, while the frail houses of the natives were with few exceptions wrecked by the winds or swept away by the floods. The results of the storm are still seen in the numerous abandoned coffee plantations and in the evidences of vanished fortunes of the planters.

As stated in a previous paragraph, Porto Rico lies in a belt of comparative freedom from the visits of hurricanes, between two fairly well-defined hurricane tracks. The Porto Rican storms of the past have all been in the first branch of the normal track, or those with a westward movement; never in the recurve or in the second branch. Hence there is never any doubt about the general direction from which to expect storms in Porto Rico; always from the east or southeast. The fact that hurricanes are of infrequent occurrence in Porto Rico is indicated by the frequent reference to the storm of August 8, 1899, or San Ciriaco, as it is called, in accordance with the custom of the people to give to these storms the name of the saint's day upon which they occur. San Ciriaco is the only hurricane of note within the memory of the present generation of Porto Ricans; the older inhabitants occasionally refer to the storm of October 29, 1867 (San Narciso), as of equal violence. Two additional storms of the nineteenth century are given place beside San Ciriaco and San Narciso in the history of Porto Rico, namely, those of August 3, 1837 (Los Angeles), and of July 26, 1825 (Santa Ana). The record of storm frequency in

Porto Rico during the past 35 years shows a decided preponderance in favor of their occurrence in August and September, and in fact none of any severity has occurred in any other month since that of San Narciso in October, 1867. A longer period of observation may, however, show a different result. In a list of 21 severe hurricanes recorded in the annals of Porto Rico since 1515, 7 occurred in July, 7 in August, 5 in September, and 2 in October. That these storms are more liable to occur during the months of August and September in Porto Rico than in other months is attested by the fact that the ecclesiastical authority, from time immemorial, ordained that priests in Porto Rico should recite in the mass the prayer "Ad repellendat tempestates" during the months of August and September, but not in October, and that in Cuba it should be recited in September and October, but not in August, showing that the ecclesiastical authority knew by experience that cyclones of October are very much to be feared in Cuba, but not those of August, and that in Porto Rico, on the contrary, the hurricanes of August are disastrous, while those of October are rare.[1]

The hurricane of August 7–20, 1899, the center of which passed over the island of Porto Rico, was in many respects a typical hurricane. It occurred in the height of the hurricane season and followed closely the normal track. It was under close observation from its appearance east of the Windward Islands on August 7 until it reached the banks of Newfoundland 12 days later. On the 8th of August the center of the storm passed directly over Porto Rico, entering at Arroyo on the southeast coast at about 8 a. m. and leaving the island between 1 and 2 in the afternoon in the vicinity of Aguadilla on the west coast. At 8 a. m., seventy-fifth meridian time, of August 7, 1899, the center of the storm was about 150 miles east-northeast of the island of Dominica, of the Windward group, in latitude about 15° north and longitude about 58° west; at Roseau the barometer read 29.72 inches, with rain and wind changing from northeast to northwest and with a velocity of 12 miles per hour. The change of wind in connection with the falling barometer indicated the approach of a storm from the east, and the Chief of the Weather Bureau ordered up hurricane signals at Roseau, Dominica, Basseterre, and St. Kitts in the Windward Islands and at San Juan, Porto Rico, and sent advisory messages to all other stations in the Lesser Antilles and to Santo Domingo, Jamaica, and to Cuban ports, with information regarding the position and probable course of the storm. During the next 24 hours the hurricane traveled in a west-northwest direction, reaching the island of Guadeloupe early in the afternoon of the 7th and the southeast coast of Porto Rico about 8 a. m. of the 8th. At St. Kitts, about 50 to 75 miles north of the center of the storm, the lowest barometer was 29.268 inches at 5 p. m. of the 7th, and the maximum wind velocity for 5 minutes was at the rate of 72 miles per hour, with an extreme velocity for 1 minute of 120 miles per hour at 4.40 p. m. The destruction of life and property was very great on the island of Guadeloupe. When the center of the storm reached Arroyo on the southeast coast of Porto Rico about 8 a. m. on the following day (8th) the barometer of the cooperative observer of the Weather Bureau in that locality read 27.75 inches, a reading but seldom recorded in the annals of storms, and sufficiently accounting for the destructive violence of wind and rain recorded along the path of the center of the storm on that day. The storm continued a north-northwest course and reached the northeast coast of Santo Domingo on the morning of the 9th. By the 12th the storm center had reached a position about 50 miles south of Nassau, Bahama Islands, in the meantime having moved 700 miles at a velocity of less than 10 miles per hour. In its passage over the Bahamas the storm was quite severe, and at Nassau the barometer fell to 29.10 inches. In the meantime all towns in the line of advance of the storm were from time to time advised concerning the probable course and intensity of the storm. By the morning of August 13 the storm center had reached a position off Jupiter, Fla., with a minimum reading of 29.22 inches. The subsequent course of the storm lay off and nearly parallel to the coast of the South Atlantic States, acquiring almost unprecedented violence off Hatteras from the 16th to the 18th, the barometer falling to 28.60 inches at 8 p. m. of the 17th.

[1] Viñes.—Huracañes. Habana, 1877, p. 13.

The following extracts from the records of the United States Weather Bureau give an excellent account of conditions preceding and during the progress of the storm across the island of Porto Rico:

Arroyo.—The order to hoist hurricane signals was received at 3 p. m. of the 7th; at 5.30 a. m. of the 8th, with a barometer reading of 29.30 inches, the hurricane began with a force estimated at 100 miles per hour. The barometer fell rapidly until 8 a. m., when it read 27.75 inches, the wind blowing from the north all the time until about 8.30 a. m., when there was a lull of about 15 minutes; the wind then changed and came with such terrific force from the south that it appeared that nothing could stand against it. The loss of property in the vicinity is estimated at about $1,000,000. All minor crops were completely destroyed.

Humacao.—The hardest wind came from the southeast, very little from the south. The loss of life was over 80. A tidal wave destroyed almost all of the houses at the port of Humacao. The estimated loss of property was about $1,000,000.

San Juan.—For several days previous to the 8th the meteorological conditions had been peculiar. During the 3d and 4th the air was almost calm. There were, however, no indications of a hurricane until the morning of the 7th, when the barometer read 29.96 inches. About noon of the 7th the sky assumed a hazy appearance and ragged cumulus and cumulo-stratus clouds were observed moving rapidly from the northeast. At that time a cablegram was received ordering up hurricane signals and announcing that the hurricane was central east of Dominica. The barometer at that time was 29.91 inches, wind northeast, velocity 12 miles per hour. The barometer continued to fall rapidly and at 3 p. m. the sky began to be covered with thick alto-stratus and stratus clouds, the former moving from the southeast and the latter from the east-northeast. The barometer stood at 29.86 inches. From that time on the sky became more and more overcast, the barometer fluctuated between 29.78 and 29.80 inches, and at 5.25 p. m. light rain began and continued until 8.15 p. m. At 10 p. m. the barometer began a downward movement which continued until the lowest recorded reading was reached, 29.23 inches, at 8.30 a. m. of the 8th, when it "pumped" violently and then began to rise and reached 29.55 inches at noon of the 8th. The wind did not attain a high velocity until 2 a. m. of the 8th. At 5 a. m. of the 8th it was blowing hard and raining, both increasing until between 7 a. m. and 9 a. m. of the 8th, when the hurricane was at its worst, an estimated wind velocity of 85 miles to 90 miles an hour being reached. A peculiar feature of the storm was that there was practically no thunder or lightning. But two flashes of lightning were observed and they were not severe. During the afternoon of the 8th the rainfall was extremely heavy, continuing into the night. The total amount during the storm was 6.37 inches, of which 4.18 inches fell between noon and 8 p. m.—*R. M. Geddings.*

The storm did very little damage in San Juan, owing to the solid construction of the buildings.

The center passed northward of Ponce and Juana Diaz, and very near to the latter town (barometer reading 28.11 inches). Reports from Ponce showed a loss of over 500 lives, mostly by drowning. The smaller fruits and vegetables were reported as utterly destroyed, and as these, with bananas, are the principal food of the inhabitants a famine was inevitable. The observer at Juana Diaz reported a rainfall of 11.20 inches from 6 a. m. of the 8th to 6 a. m. of the 9th. Along the military road from Coamo desolation reigned on every side; but two houses were left standing at Aibonito, in the mountain pass, and the road between these towns was blocked in many places by huge bowlders which were blown and washed down from the cliffs which border the road.

Arecibo.—The flood of the rivers which, by a common mouth, empty into the sea near this town, was such an enormous one that old people here have no recollection of anything to equal it. The loss of life by drowning is estimated between 500 and 1,000. Almost all the houses of the peasants living in the plains and higher up along the river sides have been carried to the sea or destroyed, while the lower part of the town was several meters under water.

Mayaguez.—The barometer reached the lowest point at about 1.25 p. m. of the 8th. In the city the damage to property was large, and from the country the news is appalling. One-fourth of the coffee crop only will be saved; the loss of cane was considerable, and crops of minor fruits, which are the sustenance of the poor, have disappeared. The loss of life is greater than ever before, houses with all inmates being washed away by the floods.

Aguadilla.—The wind began blowing about 8 a. m. of the 8th and increased in force to about 1 p. m., when perfect stillness reigned up to about 2 p. m.; after that the wind blew from the south, sometimes with tremendous velocity, until 7 p. m., after which it slackened gradually.

Further details concerning the weather conditions at San Juan from August 5 to 9 are shown upon Plate XVI for every hour of the day and night; the changes preceding and accompanying the storm are indicated for clouds, temperature, pressure, wind direction and velocity, humidity, sunshine, and rainfall. The unprecedented fall in the barometer at Arroyo, on the south coast of the island, as the center of the storm passed, is also shown. The path of the storm over the island, its hourly rate of movement, and the total amount and duration of rainfall are shown on Plate XVII. The center of the storm crossed the island in about six hours, or at the rate of about 12 miles per hour. At San Juan a wind of storm velocity (40 miles per hour) began at 5 a. m. and continued until 10 a. m. This would indicate a width of 60 miles for the cross section of the storm proper at San Juan. Judging from the reports from Arroyo, the cross section of the storm, based upon a wind velocity of 40 miles per hour, was from 80 to 85 miles. The average duration of rainfall over the island during the progress of the storm was about 28 hours. With a progressive movement of 12 miles per hour, the cross section of the rain area would be about 335 miles. The approximate daily movement of the storm along its entire path from the Windward Islands westward to Florida and then along the Atlantic coast to the banks of Newfoundland is shown in the following figures:

Progressive movement of hurricane of Aug. 7–20, 1899.

[In miles per day.]

Date.	In the first branch.	Date.	In the recurve.	Date.	In the second branch.
Aug. 8	275	Aug. 13	200	Aug. 15	175
9	275	14	150	16	140
10	175			17	125
11	150			18	100
12	200			19	75
				20	225
Means	200	Means	175	Means	150

The slow progressive movement of this storm in the second branch is exceptional. (See Pl. XVIII.)

The successive changes in weather conditions during the passage of a hurricane to the north and south of and over Porto Rico are shown on Plates XVII, and XIX–XXII.

On the 6th of September, 1910, during the passage of a general storm to the south of Porto Rico, a local storm of great violence passed over the northeastern portion of the island, resulting in great damage to property as a result of excessively heavy rains and unprecedented floods; the rainfall over a portion of the island exceeded in intensity even the very heavy rains recorded during the hurricane of August 8, 1899. (See Pls. XXIII and XXIV.)

ORIGIN OF TROPICAL CYCLONES.

The similarity in geographical area of hurricanes, cyclones, and typhoons, in the paths followed, in their rate of movement, in their intensity, and in their periods of occurrence suggests a similar mode of origin for all of these tropical storms. The theory, dominant for many years,

that storms have their origin in local differences in temperature, and consequently in differences in resulting convection currents, has probably retarded the development of a satisfactory theory of storms by directing attention too much to local conditions within the storm area, rather than to the larger atmospheric movements, having their centers at great distances from the storm center. The extent of the influence of remote atmospheric conditions upon the development and progress of disturbances in a particular locality has only in recent years begun to be realized: The eruption of the volcano Krakatoa near the island of Java in the fall of 1883 threw vast volumes of dust into the higher strata of the atmosphere, the finest particles of which were carried many times around the globe in the westward drift of the high air strata, causing the brilliant sunsets observed for many months thereafter. The atmospheric waves caused by the shock of the eruption were indicated by barometers upon the opposite side of the globe. The great monsoon winds of India were for a long time regarded as results of certain conditions of temperature and precipitation existing within the peninsula of India, but are now known to be due to the conditions of pressure over vast areas thousands of miles distant. The explanation of the origin of hurricanes and other tropical cyclones will doubtless be found in the seasonal variations in the position and intensity of the extensive areas of high and low pressure to which M. Teisserenc de Bort has given the name of "centers of action of the atmosphere." The high areas of this group are found within a belt of high pressure surrounding the globe between the parallels of latitude of 30° and 40° in the Southern and Northern Hemispheres, with peaks of greater development over the oceans during the warm season in the Northern Hemisphere and at all times in the Southern Hemisphere. The low areas, during the season of tropical cyclones, are over the southern portion of the Asiatic continent and over the west-central portion of North America, with a belt of comparatively low pressure in the equatorial zone at all seasons of the year. That an intimate connection exists between these permanent areas of high pressure in the North Atlantic and the hurricanes of the West Indies was recognized many years ago. In an investigation of the typical hurricane of August, 1873, Capt. Toynbee [1] came to the conclusion that this storm "followed the law which governs areas of low pressure over Europe in passing *outside* instead of advancing into areas of high pressure; hence when it is known that a hurricane exists in the neighborhood of the West Indies, it may perhaps be possible to predict its further track if the disposition of pressure is known over these islands, Bermuda and America." Daily weather charts of the North Atlantic were prepared by Capt. Toynbee for the month of August, 1873, showing the entire course of the remarkable hurricane of that month—from its origin off the west coast of Africa, about the 10th of August, to its recurve in the vicinity of Bermuda on the 22d, and to its final dissolution off the coast of Norway on September 2. Off the west coast of Africa, between 10° and 15° north latitude there is a permanent area of low pressure. Bearing to the northwest is the center of the North Atlantic high, and to the south the center of the South Atlantic high area. The northeast trades and the southwest monsoons blow toward this center of low pressure. In the late summer and early fall the force of these opposing winds is frequently very high, giving rise to conditions favorable for the formation of a cyclonic circulation. The whirl being formed is carried westward in the general atmospheric drift above the tropical zone. A careful examination of these charts from the 1st to the 10th of August shows that the northeast trade and the southwest monsoon were often in close proximity over that part of the ocean which lies to the southwest of the Cape Verde Islands. On the 11th, 12th, and 13th there was an imperfectly developed cyclonic movement in the winds in this locality. From this time onward until the close of the month the course of the storm was along the edge of the North Atlantic area of high pressure, approximately parallel with the isobar of 30 inches. (See Plate XVIII.)

The atmospheric conditions which give rise to cyclonic storms are graphically described by Eliot [2] in the following paragraphs from his Handbook:

Whenever a moist air current is blowing, there is always a tendency to the formation and occurrence of rain squalls. This tendency is apparently very much increased if the moist air current meets with any sudden obstruction, or if it

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[1] Toynbee: Meteorology of the North Atlantic in August, 1873. 4°. London, 1878.
[2] Eliot, J. Handbook of Cyclonic Storms in the Bay of Bengal. 8°. Calcutta, 1900.

advances toward another air current which differs much in temperature, humidity, or other characteristic features. Hence, in front of the advancing southwest monsoon up the Bay of Bengal in the months of May and June there are always frequent rain squalls. These squalls appear to be very frequent in the neighborhood of Ceylon just before the southwest monsoon current enters the bay in May.

There is no doubt that what is ordinarily called the southwest monsoon in India commences at the entrance of the bay and works up the bay. It marches up the bay in a more or less rapid rush at a rate of sometimes as much as 200 to 300 miles a day. Before it advances over the center of the bay during the latter part of May or beginning of June, light unsteady winds usually prevail; whilst near the head of the bay local southwest winds blow across the coast into Bengal.

The first advance of monsoon winds over the south and center of the bay apparently resembles to some extent the sudden advance of a rapidly moving fluid mass into an inert mass, and there is much irregular and whirling motion. This shows itself by the frequent occurrence of squalls.

During the prevalence of the southwest monsoon the winds blow intermittently; that is, strongly for some days, and then fall off in strength. During these weak intervals the amount of rain in northern India is comparatively small. These intervals of fine weather form what are called "breaks in the rains." During these breaks there is a tendency for the southwest monsoon to back down the head of the bay. *After some little time, and apparently under the increasing pressure of the winds in the south of the bay, it advances again. Each advance is similar in character to the first great burst of the monsoon in May or June. It is a rush of strong winds over an area previously occupied by feeble winds, and is attended with more or less squally weather.* Hence, squalls are of frequent cocurrence over the bay at the commencement of the monsoon, and over the north of the bay during the whole monsoon period from May or June to October. As already pointed out, the air current which gives rise to these squalls is a damp humid current, bringing up vast quantities of aqueous vapor, and hence having a vast store of energy. If this energy be released and set free rapidly, the squally weather, which indicates slight atmospheric disturbance, may gather strength and grow into a large cyclonic storm.

Similar conditions are doubtless produced within the hurricane area of the West Indies by the advance of the North Atlantic high into the region of calms, or by the conflict between the opposing winds of the North and South Atlantic high areas, resulting in the formation of hurricanes, just as the advance and the retreat of the high area over the southern Indian Ocean gives rise to the southwest monsoon and the squalls and cyclones over the Bay of Bengal. (See Plate XXV.)

TABLE I.—LATITUDE AND LONGITUDE OF ORIGIN AND RECURVE OF 134 HURRICANES.

Hurricanes of the West Indies—Position of origin and recurve.

Time.	Origin.		Recurve.		First day after recurve.		Position of origin.
	Lat.	Long.	Lat.	Long.	Lat.	Long.	
	N.	W.	N.	W.	N.	W.	
May 16–20, 1889	22	65	30	75	32	72	F.
June 20–22, 1886	20	86	24	86	30	85	S.
June 27–30, 1886	16	80	25	90	28	88	F.
June 15–18, 1889	20	85	22	86	28	83	R.
June 11–14, 1901	19	86	22	84	23	85	R.
June 12–16, 1902	18	79	30	84	34	80	R.
June 9–17, 1906	22	90	40	90	......	......	F.
June 14–18, 1906	24	72	25	82	27	80	F.
June 28–30, 1909	18	86	35	94	......	......	F.
July 14–20, 1886	19	83	28	88	29	84	F.
July 30–31, 1886	26	85	......	......	32	82	S.
July 20–28, 1887	15	61	20	87	25	86	F.
July 5–10, 1901	19	78	35	100	......	......	F.
July 8–10, 1901	19	72	28	77	37	73	R.
Aug. 12–18, 1878	15	78	......	......	......	......	F.
Aug. 14–18, 1879	15	66	25	78	35	77	F.
Aug. 20–24, 1879	18	88	28	96	33	94	F.
Aug. 7–13, 1880	14	79	......	......	......	......	F.
Aug. 15–20, 1880	18	58	20	79	26	76	F.
Aug. 26–31, 1880	28	68	35	95	......	......	F.
Aug. 28–31, 1880	24	59	33	66	36	64	F.
Aug. 23–29, 1881	20	64	38	92	......	......	F.
Aug. 23–24, 1883	22	58	32	70	......	......	F.
Aug. 28–29, 1883	26	66	34	72	......	......	F.
Aug. 24–25, 1885	28	80	32	80	37	75	R.
Aug. 12–18, 1886	11	59	......	......	......	......	F.
Aug. 16–28, 1886	13	61	21	81	28	78	F.
Aug. 19–20, 1886	26	92	......	......	......	......	F.
Aug. 5–7, 1887	17	72	......	......	......	......	F.
Aug. 16–20, 1887	22	65	30	79	37	74	F.
Aug. 19–24, 1887	17	59	28	78	29	78	F.
Aug. 16–20, 1888	26	78	30	92	35	89	F.
Aug. 19–25, 1889	17	70	28	75	32	75	F.
Aug. 22–25, 1889	24	83	25	87	32	75	F.
Aug. 28–31, 1890	19	57	30	70	35	68	F.
Aug. 19–25, 1891	15	62	......	......	......	......	F.
Aug. 15–21, 1893	16	60	28	76	32	75	F.
Aug. 24–27, 1893	20	58	33	82	......	......	F.
Aug. 4–9, 1894	24	86	......	......	......	......	F.
Aug. 14–17, 1895	29	92	......	......	30	90	S.
Aug. 24–29, 1895	14	70	......	......	......	......	F.
Aug. 7–16, 1899	16	60	29	80	32	79	F.
Aug. 6–9, 1901	20	76	25	74	34	74	R.
Aug. 9–15, 1901	19	75	29	90	32	89	F.
Aug. 8–15, 1903	14	58	......	......	......	......	F.
Aug. 26–31, 1904	24	85	29	86	32	80	S.
Aug. 21–27, 1909	18	62	35	100	......	......	F.
Aug. 27–31, 1909	19	67	28	82	33	77	F.
Aug. 27–29, 1911	25	67	33	80	......	......	F.
Sept. 16–18, 1876	20	58	28	60	35	58	R.
Sept. 1–12, 1878	11	60	25	82	27	82	F.
Sept. 24–30, 1878	15	71	23	74	26	73	R.

[1] F= in first branch; S=second branch; R=in recurve.

Table I.—Latitude and Longitude of Origin and Recurve of 134 Hurricanes—Continued.

Hurricanes of the West Indies—Position of origin and recurve—Continued.

Time.	Origin.		Recurve.		First day after recurve.		Position of origin.
	Lat.	Long.	Lat.	Long.	Lat.	Long.	
	N.	W.	N.	W.	N.	W.	
Sept. 12-23, 1879	16	68	23	88	26	86	F.
Sept. 7-9, 1881	25	70	35	78			F.
Sept. 3-7, 1882	21	72	27	28	34	82	F.
Sept. 5-11, 1883	15	66	30	79	32	78	F.
Sept. 6, 1884	19	58	19	58			R.
Sept. 17-22, 1885	22	96	25	98	28	96	R.
Sept. 24-30, 1885	24	89	26	93	30	89	F.
Sept. 27-28, 1885	30	58	34	59			R.
Sept. 15-25, 1886	14	62	28	97	35	94	F.
Sept. 26-30, 1886	22	66	30	72			F.
Sept. 11-22, 1887	14	59					F.
Sept. 1-10, 1888	19	62					F.
Sept. 8-10, 1888	26	80	28	84	33	81	F.
Sept. 24-26, 1888	27	79			32	76	S.
Sept. 1-8, 1889	15	60	24	69	29	67	F.
Sept. 15-24, 1889	14	78	24	92	28	90	F.
Sept. 6-7, 1891	26	71	30	72			R.
Sept. 19-22, 1891	26	58	34	65			F.
Sept. 12-13, 1892	27	91			35	86	S.
Sept. 6-10, 1893	26	91	28	94	30	91	F.
Sept. 27-29, 1896	23	86			26	83	S.
Sept. 10-14, 1898	13	58	25	74			F.
Sept. 25-26, 1898	24	84			27	77	S.
Sept. 1-4, 1899	16	63	20	73	30	68	F.
Sept. 8-13, 1899	18	62	26	66	34	64	R.
Sept. 1-10, 1900	15	65	30	98			F.
Sept. 14-18, 1900	21	62	26	67	39	57	F.
Sept. 12-18, 1901	18	69	28	90	32	82	F.
Sept. 27-29, 1901	27	83	30	83			R.
Sept. 13-16, 1903	28	65	35	75			F.
Sept. 11-18, 1904	20	74	34	78	37	74	F.
Sept. 27-29, 1905	25	92	30	73			R.
Sept. 1-9, 1906	15	35	28	76	32	72	F.
Sept. 11-21, 1906	21	55	40	90			F.
Sept. 20-27, 1906	17	78	35	92			F.
Sept. 18-23, 1907	22	79	28	88	32	86	F.
Sept. 28-29, 1907	25	91			33	81	S.
Sept. 8-26, 1908	12	58	26	76	28	72	F.
Sept. 23-30, 1908	14	58	23	77	25	75	F.
Sept. 16-22, 1909	16	81	35	92			F.
Sept. 23-28, 1909	14	74	25	85	28	80	F.
Sept. 6-10, 1910	16	67					F.
Oct. 1-5, 1878	25	72	28	72	29	71	R.
Oct. 18-23, 1878	17	80	21	81	29	79	R.
Oct. 10-16, 1879	16	68	33	89			F.
Oct. 8-13, 1882	22	83	24	84	28	83	S.
Oct. 22-23, 1883	27	78			33	76	S.
Oct. 11-17, 1884	20	74	25	76	28	72	R.
Oct. 8-13, 1886	22	83	28	93	34	92	F.
Oct. 22-24, 1886	17	70			25	66	R.
Oct. 9-11, 1887	19	80					F.
Oct. 11-20, 1887	16	75	25	98	29	95	F.
Oct. 10-11, 1888	28	85			34	79	S.
Oct. 1-5, 1889	16	61	28	68	34	63	F.
Oct. 5-7, 1889	24	82			30	80	S.
Oct. 1-2, 1891	26	68			33	59	S.
Oct. 2-5, 1891	26	58	35	69			F.
Oct. 9-11, 1891	26	83			29	80	S.
Oct. 13-18, 1891	16	63	27	71	30	69	F.
Oct. 23-26, 1892	28	90			30	80	S.
Oct. 7-13, 1893	22	58	29	79			F.
Oct. 20-22, 1893	26	86			22	82	S.
Oct. 3-9, 1894	17	82	24	88	30	86	F.
Oct. 13-18, 1894	17	63	26	67	33	62	F.
Oct. 23-26, 1894	22	61	27	76	35	70	F.
Oct. 1-5, 1895	25	83			26	80	S.
Oct. 20-23, 1895	20	80	23	80	26	78	R.
Oct. 30-31, 1895	27	97			30	88	S.
Oct. 3-6, 1899	21	82	26	84	34	77	R.
Oct. 26-31, 1899	19	78	22	82	24	80	F.
Oct. 5-16, 1900	25	65	27	72	35	66	F.
Oct. 10-16, 1900	26	88			32	81	S.
Oct. 27-30, 1900	25	75	25	75	30	73	R.
Oct. 22-25, 1903	20	76			29	74	S.
Oct. 15-20, 1904	21	78	23	84	27	82	F.
Oct. 30-31, 1904	32	68			33	65	S.
Oct. 3-10, 1906	12	83			14	81	S.
Oct. 14-21, 1906	22	96			22	93	S.
Oct. 22-25, 1906	30	72			32	68	S.
Oct. 7-14, 1907	16	63	20	76	23	73	F.
Oct. 20-30, 1908	28	67	25	87	30	84	F.
Oct. 6-13, 1909	12	73	22	84	28	77	F.
Oct. 11-13, 1909	21	86			26	77	S.
Oct. 14-20, 1910	22	84			27	82	S.
Nov. 17-25, 1888	23	59	24	78	28	76	F.
Nov. 1-3, 1904	32	68			33	65	S.
Nov. 14-19, 1910	27	100			27	98	S.

Mean paths.

Months.	Number of storms.	Origin.		Recurve.		First day, second branch.		Position of origin in—		
		Lat.	Long.	Lat.	Long.	Lat.	Long.	First branch.	Recurve.	Second branch.
		N.	W.	N.	W.	N.	W.	*Per ct.*	*Per ct.*	*Per ct.*
June	8	20	83	28	87	28	84	50	38	12
July	5	20	76	27	87	30	81	60	20	20
August	33	20	70	30	83	33	79	87	6	6
September	45	20	71	28	81	30	80	69	20	11
October	42	22	76	25	80	29	78	40	17	43
May-November	136	20	73	28	82	30	79	63	17	20

Table II.—Annual Mean Paths of Hurricanes.

Year.	Number of storms.	Origin. Lat.	Origin. Long.	Recurve. Lat.	Recurve. Long.	Year.	Number of storms.	Origin. Lat.	Origin. Long.	Recurve. Lat.	Recurve. Long.
		N.	W.	N.	W.			N.	W.	N.	W.
1876	1	20	58	28	60	1896	1	23	86	23	86
1877	0	....	....	....	....	1897	0	....	....	....	....
1878	5	17	72	24	77	1898	2	18	71	25	74
1879	4	15	66	25	78	1899	5	18	69	25	77
1880	4	21	66	29	89	1900	5	20	76	28	93
1881	2	22	67	36	85	1901	7	20	77	28	85
1882	2	22	78	26	86	1902	1	18	79	30	84
1883	4	22	59	31	75	1903	3	21	66	28	76
1884	2	20	66	22	67	1904	5	24	76	29	79
1885	4	26	81	29	82	1905	1	....	....	....	....
1886	11	19	79	26	88	1906	8	20	74	29	85
1887	11	17	67	26	86	1907	3	21	78	24	82
1888	6	25	74	30	88	1908	3	20	68	26	84
1889	8	19	73	26	78	1909	7	17	76	29	89
1890	1	19	57	30	70	1910	3	24	92	24	97
1891	7	23	66	32	69	1911	1	25	67	33	80
1892	2	28	90	28	96	Total	143	....	....	....	....
1893	5	22	71	29	82	Means	....	21°	73°	28°	82°
1894	4	20	73	26	77						
1895	5	23	84	26	96						

Table III.—Daily Progressive Movement of 138 Hurricanes.

[In miles per day.]

Time.	Days preceding. 5	4	3	2	1	Recurve.		Days following. 11	N'n.
May 16–20, 1889	....	....	150	300	350	200	....	200	....
June 20–22, 1886	....	....	....	....	....	350	....	400	....
June 27–30, 1886	....	....	....	....	500	300	200	500	....
June 15–18, 1889	....	....	....	....	....	200	350	350	....
June 11–14, 1901	....	....	200	175	150	....	....	....	....
June 12–16, 1902	....	....	....	....	400	275	300	300	300
June 9–17, 1906	....	200	250	125	350	300	250	400	309
June 14–18, 1906	....	....	....	....	200	100	200	400	300
June 28–30, 1909	....	....	....	500	500	....	....	....	....
July 14–20, 1886	....	....	....	175	199	325	225	225	350
July 30–31, 1886	....	....	....	....	....	....	....	400	....
July 20–28, 1887	300	250	275	300	500	300	310	....	....
July 5–10, 1901	225	150	100	275	300	....	....	....	....
July 8–10, 1901	....	....	....	....	....	300	550	....	....
Aug. 12–18, 1878	....	....	200	300	300	250	225	....	....
Aug. 14–18, 1879	....	....	....	350	300	450	650	....	....
Aug. 20–24, 1879	....	....	....	....	150	300	300	....	....
Aug. 7–13, 1880	100	250	225	125	125	200	....	....	....
Aug. 15–20, 1880	....	425	300	200	200	500	400	....	....
Aug. 26–31, 1880	300	275	300	200	250	....	....	....	....
Aug. 28–31, 1880	....	....	....	215	275	150	....	....	....
Aug. 23–29, 1881	175	200	225	250	350	....	....	....	....
Aug. 23–24, 1883	....	....	....	....	950	....	....	....	....
Aug. 28–29, 1883	....	....	....	....	350	....	....	....	....
Aug. 24–25, 1885	....	....	....	....	....	250	....	300	....
Aug. 12–18, 1886	200	285	300	325	500	....	....	....	....
Aug. 19–20, 1886	....	....	....	....	300	....	....	....	....
Aug. 5–7, 1887	....	....	....	225	250	....	....	....	....
Aug. 16–20, 1887	....	....	400	200	175	525	....	....	....
Aug. 19–24, 1887	....	....	500	500	150	225	220	200	....
Aug. 16–20, 1888	....	....	400	275	75	100	....	400	....
Aug. 19–25, 1889	....	....	....	....	....	175	150	....	....
Aug. 22–25, 1889	....	....	....	....	100	150	900	....	....
Aug. 19–25, 1891	300	200	215	200	310	....	....	....	....
Aug. 15–21, 1893	....	....	275	250	250	300	400	....	....
Aug. 24–27, 1893	....	....	400	450	600	....	....	....	....
Aug. 4–9, 1894	....	....	....	....	....	200	100	....	....
Aug. 14–17, 1895	....	....	....	....	....	150	200	....	....
Aug. 24–29, 1895	675	350	300	250	250	....	....	....	....
Aug. 7–16, 1899	310	175	175	200	210	185	200	175	....
Aug. 6–9, 1901	....	....	....	....	....	150	150	....	....
Aug. 9–15, 1901	400	200	150	175	125	100	125	....	....
Aug. 8–15, 1903	400	300	275	300	250	....	....	....	....
Aug. 26–31, 1904	....	....	....	....	....	200	....	450	200
Aug. 21–27, 1909	300	500	400	400	350	....	....	....	....
Aug. 27–31, 1909	....	....	....	350	600	300	100	300	150
Aug. 27–29, 1911	....	....	....	....	....	....	....	....	....
Sept. 16–18, 1876	....	....	....	....	....	400	400	....	....
Sept. 1–12, 1878	350	300	200	200	125	200	75	....	....
Sept. 24–30, 1878	....	....	....	....	140	150	100	....	....
Sept. 12–23, 1879	....	....	....	....	....	150	200	200	200
Sept. 7–9, 1881	....	....	....	450	200	....	....	....	....
Sept. 3–7, 1882	240	250	150	200	225	150	525	....	....
Sept. 5–11, 1883	....	500	175	200	175	175	175	225	....
Sept. 6, 1884	....	....	....	....	....	....	....	....	....
Sept. 17–22, 1885	....	....	....	....	....	250	....	100	100
Sept. 24–30, 1885	....	....	....	....	200	400	....	50	50
Sept. 27–28, 1885	....	....	....	....	250	....	....	....	....
Sept. 15–25, 1886	315	550	650	300	100	100	250	150	....
Sept. 26–30, 1886	....	....	250	200	175	85	....	....	....
Sept. 11–22, 1887	300	200	175	250	200	150	150	....	....
Sept. 1–10, 1888	250	350	300	150	300	....	....	....	....
Sept. 8–10, 1888	....	....	....	....	....	300	....	300	....
Sept. 24–26, 1888	....	....	....	....	....	....	....	....	....
Sept. 1–8, 1889	....	....	....	....	....	250	400	....	....
Sept. 15–24, 1889	....	....	250	250	200	150	225	225	400

Table III.—Daily Progressive Movement of 138 Hurricanes—Continued.

Time.	Days preceding. 5	4	3	2	1	Recurve.		Days following. 11	N'n.
Sept 6-7, 1891									
Sept. 19-22, 1891					300	200	200		
Sept. 12-13, 1892								600	
Sept 6-10, 1893						300	150		
Sep. 27-29, 1896						175	300	300	
Sept. 10-14, 1898			100	300	400	450			
Sept. 25-26, 1898								450	
Sept. 1-4, 1899				400	200	100	300	400	
Sept. 8-13, 1899				240	200	200	200	300	
Sept. 1-10, 1900	100	225	100	400	250	150	350	1,200	1,050
Sept. 14-18, 1900					150	150	300	800	
Sept. 12-18, 1901				300	150	200		400	1,000
Sept. 27-29, 1901						200	225		
Sept. 13-16, 1903				300	350	225	200		
Sept. 11-18, 1904						500	400	700	1,600
Sept. 27-29, 1905						150	150		
Sept. 1-9, 1906	200	300	100	200	125	250		300	200
Sept. 11-21, 1906	300	200	150	150	400	350	250	1,100	
Sept. 20-27, 1906			150	100	150	300	350	400	
Sept. 18-23, 1907				350	350	150		100	350
Sept. 28-29, 1907									
Sept. 8-26, 1908		200	250	375	175	100	250	400	150
Sept. 23-30, 1908	300	200	350	100	75	100	200	350	75
Sept. 16-22, 1909			250	150	200	200	500		
Sept. 23-28, 1909				275	350	300	325	300	
Sept. 6-10, 1910									
Oct. 1-5, 1878						150	75	75	75
Oct. 18-23, 1878					100	125	150	500	
Oct. 10-16, 1879	175	400	350	400	300				
Oct. 8-13, 1882						150	250	450	150
Oct. 22-23, 1883						400			
Oct. 11-17, 1884						100	125	200	300
Oct. 8-13, 1886		185	100	100	400	400			
Oct. 22-24, 1886						550		400	
Oct. 9-11, 1887				300	150				
Oct. 11-20, 1887	150	200	100	200	500	325		300	500

Time.	Days preceding. 5	4	3	2	1	Recurve.		Days following. 11	N.n.
Oct. 10-11, 1888								600	
Oct. 1-5, 1889				150	300	500		500	
Oct. 5-7, 1889								500	400
Oct. 1-2, 1891								600	
Oct. 2-5, 1891				175	300	400			
Oct. 9-11, 1891								250	400
Oct. 13-18, 1891				100	175	400	250	300	400
Oct. 23-26, 1892								600	200
Oct. 7-13, 1893		300	200	215	150	250	315		
Oct. 20-22, 1893									
Oct. 3-9, 1894				350	240	300	300	300	
Oct. 13-18, 1894						200	200	300	
Oct. 23-26, 1894				400	400	150	600		
Oct. 1-5, 1895								200	250
Oct. 20-23, 1895						200		200	350
Oct. 30-31, 1895								600	
Oct. 3-6, 1899						350	225	500	
Oct. 26-31, 1899					150	100	150		
Oct. 5-16, 1900				125	150	100	150	400	500
Oct. 10-16, 1900								400	500
Oct. 27-30, 1900						150	150	300	
Oct. 22-25, 1903						350	650	800	700
Oct. 15-20, 1904				200	150	100		150	
Oct. 30-31, 1904								200	700
Oct. 3-10, 1906								200	200
Oct. 14-21, 1906								250	200
Oct. 22-25, 1906								200	300
Oct. 7-14, 1907				500	250	200	150	400	900
Oct. 20-30, 1908	100	300	325	250	50	150	500	600	600
Oct. 6-13, 1909			150	150	200	150	200	500	600
Oct. 11-13, 1909								600	600
Oct. 14-20, 1910								100	150
Nov. 17-25, 1888		200	250	200	300	150		200	350
Nov. 1-3, 1904								250	200
Nov. 14-19, 1910						200	200	200	250

Average movement.

Period.	Number of storms.	Days preceding. 5	4	3	2	1	Recurve. 1	2	Days following. 1	2	3
June	8		200	225	267	333	254	283	390	300	150
July	5	262	200	188	250	330	331	362	225	350	
August	33	316	287	288	270	292	235	280	383	356	200
September	45	257	291	223	257	236	225	254	408	495	404
October	42	142	264	196	234	242	256	255	404	428	497
Mean for season (May-November)	137	267	274	241	256	266	240	267	387	420	437
				260			260		400		
General average											300

TABLE IV.—THE FREQUENCY OF TROPICAL CYCLONES.

Hurricanes of the West Indies (36 years).

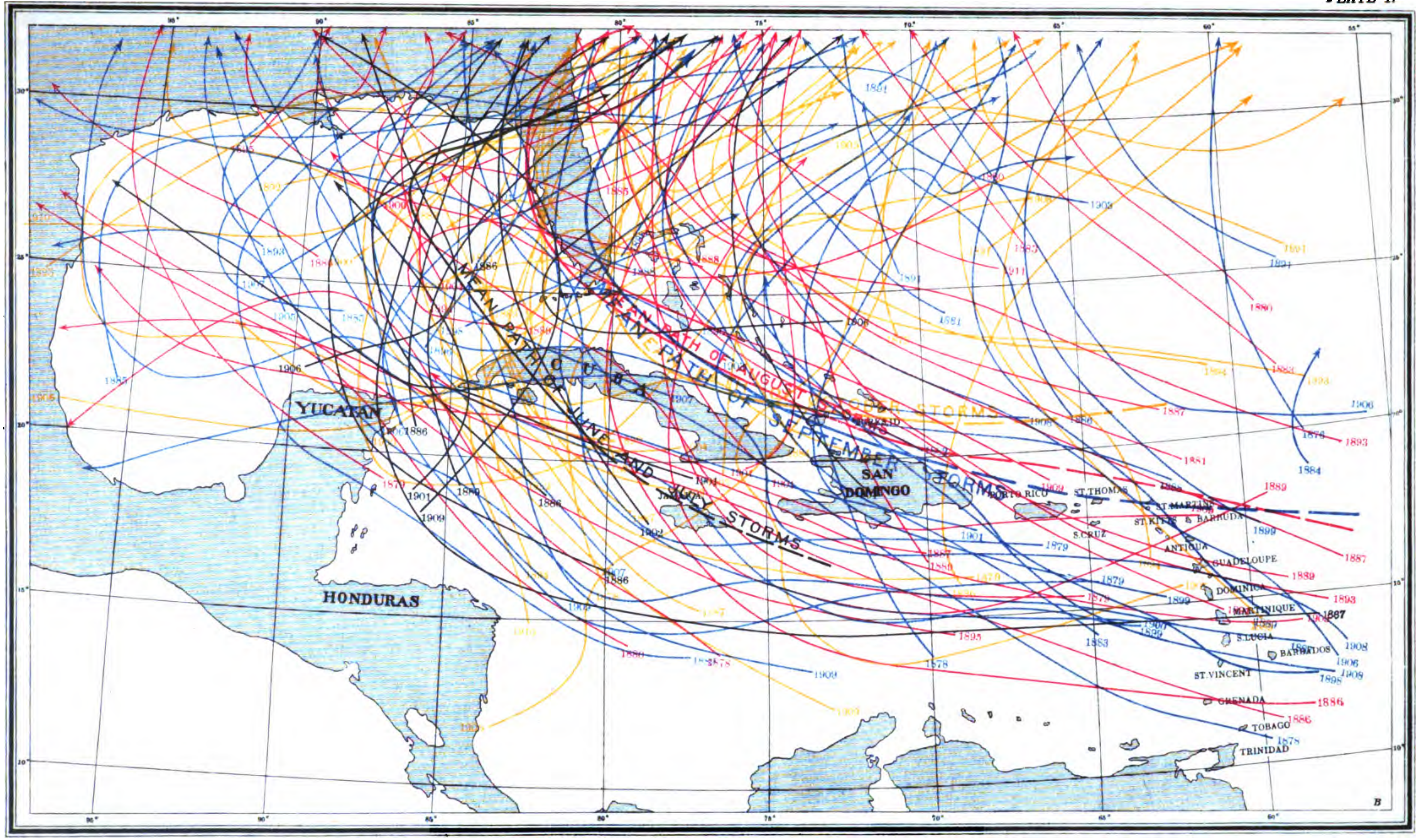
Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1876									1				1
1877													0
1878								1	2	2			5
1879								2	1	1			4
1880								4					4
1881								1	1				2
1882									1	1			2
1883								2	1	1			4
1884									1	1			2
1885								1	3				4
1886						2	2	3	2	2			11
1887							1	3	1	4		2	11
1888								1	3	1	1		6
1889					1	1		2	2	2			8
1890								1					1
1891								1	2	4			7
1892									1	1			2
1893								2	1	2			5
1894								1		3			4
1895								2		3			5
1896									1				1
1897													0
1898									2				2
1899								1	2	2			5
1900									2	3			5
1901						1	2	2	2				7
1902						1							1
1903								1	1	1			3
1904								1	1	2	1		5
1905									1				1
1906						2			3	3			8
1907									2	1			3
1908									2	1			3
1909						1		2	2	2			7
1910									1	1	1		3
1911								1					1
Total frequency					1	8	5	35	45	44	3	2	143
Average frequency								1	1	1			4
Per cent of frequency					1	6	4	25	32	31	1		

Cyclones of the Bay of Bengal (23 years).

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1876													
1877					1		1	4	1		1		8
1878							1	2	2	2	1	1	9
1879					2			1	2	2	2		9
1880						2	1	2	2	1	1		9
1881					1	3	2	2	1	1	1		11
1882							4	1	3	2	2		12
1883						2	4	1			2		9
1884					1	2	3	1	2	3	1	1	14
1885						2	2	1	2		2		9
1886					1	1	1	1	2	1	2	1	10
1887					1	2	2	2	2	1			10
1888					1		2	2	2	2		1	10
1889						2	2	2	1	2	1	2	12
1890					1	1	2		1	2			7
1891							1	1	4		2		8
1892						1	1	1	2	3			8
1893					1	1	1		3	2	1		9
1894						1	3		1	2			7
1895						2	2	1	3			1	9
1896						2	2	3	1				8
1897					1	1	1	1	2	2		1	9
1898					1	1	1	1	2	1	1		8
1899								2	2	1			5
1900													
1901													
1902													
1903													
1904													
1905													
1906													
1907													
1908													
1909													
1910													
1911													
Total frequency					12	26	39	32	43	30	20	8	210
Average frequency					0.5	1	2	1	2	1	1	0.4	9
Per cent of frequency					6	12	19	15	20	14	10	4	

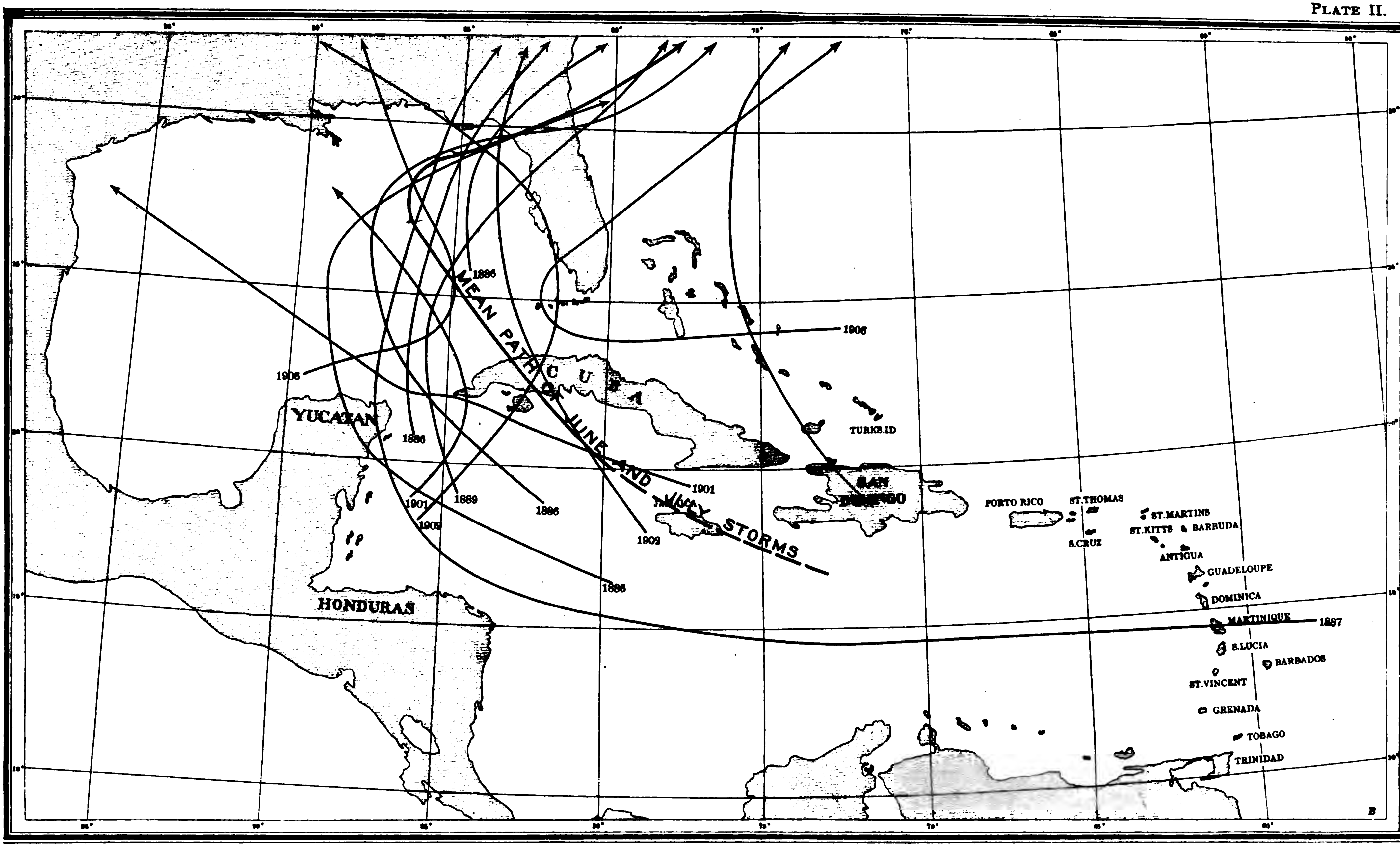
Typhoons of the Pacific (22 years).

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1876													
1877													
1878													
1879													
1880							2	4	2	2	1		11
1881					2	1	3	4	4	3	3	1	21
1882				1			3		2	2	1	2	11
1883			1	1	3	1	3	4	4	4	1		22
1884					2	1	4	5	4		2	2	21
1885				1		2	2	2	1	1	1	1	11
1886				1	1	2		3	4	3	1	1	16
1887			1	3	3	1	5	2	7	3	3		28
1888				1		2	4	3	3	1	1	1	16
1889							2	3	2	4	1	2	14
1890					1	5	4	2	7	6	1		27
1891				1	2	2	7	5	6		4	1	28
1892	1					3	4	4	5	2	3	2	24
1893					2	1	3	4	6	3	2	1	24
1894					4	3	5	3	5	5	6	3	34
1895					1	4	2	3	5	3	5		24
1896					1	2	4	4	5	4			20
1897						2	6	2	3	5	2		20
1898			1		2	3	3	6	4	3	2	1	25
1899				1	1	1	4	3	4	2	4	1	21
1900						3	1	5	3	3	4	3	23
1901	2	2	2			2	3	3	2	6	3	2	27
Total frequency	9	2	5	10	25	41	74	74	88	65	51	24	468
Average frequency	0.4	0.1	0.2	0.5	1	2	3	3	4	3	2	1	21
Per cent of frequency	2	0.4	1	2	5	9	16	16	19	14	11	5	



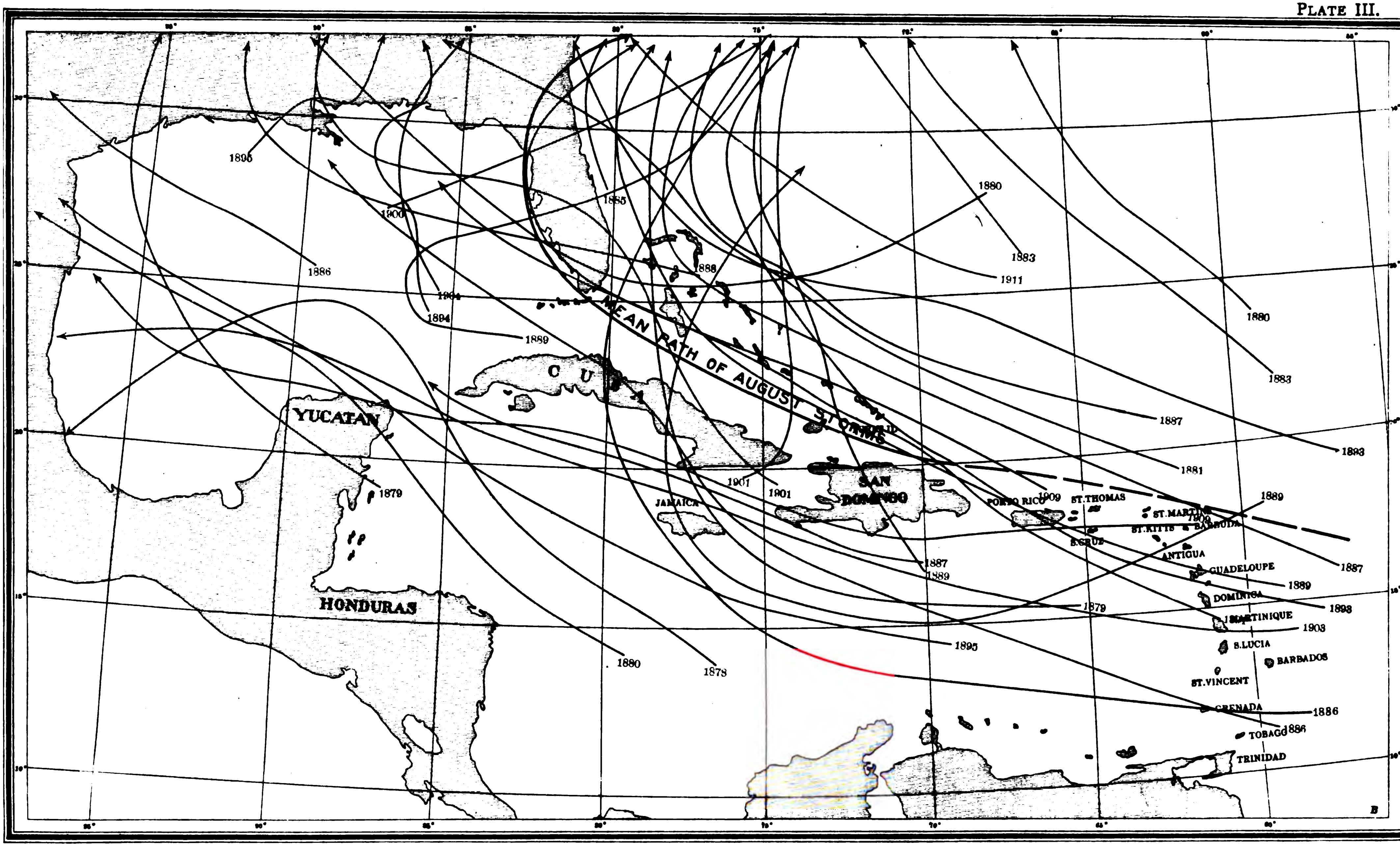
PATHS OF WEST INDIAN HURRICANES FROM 1876 TO 1911.

PLATE II



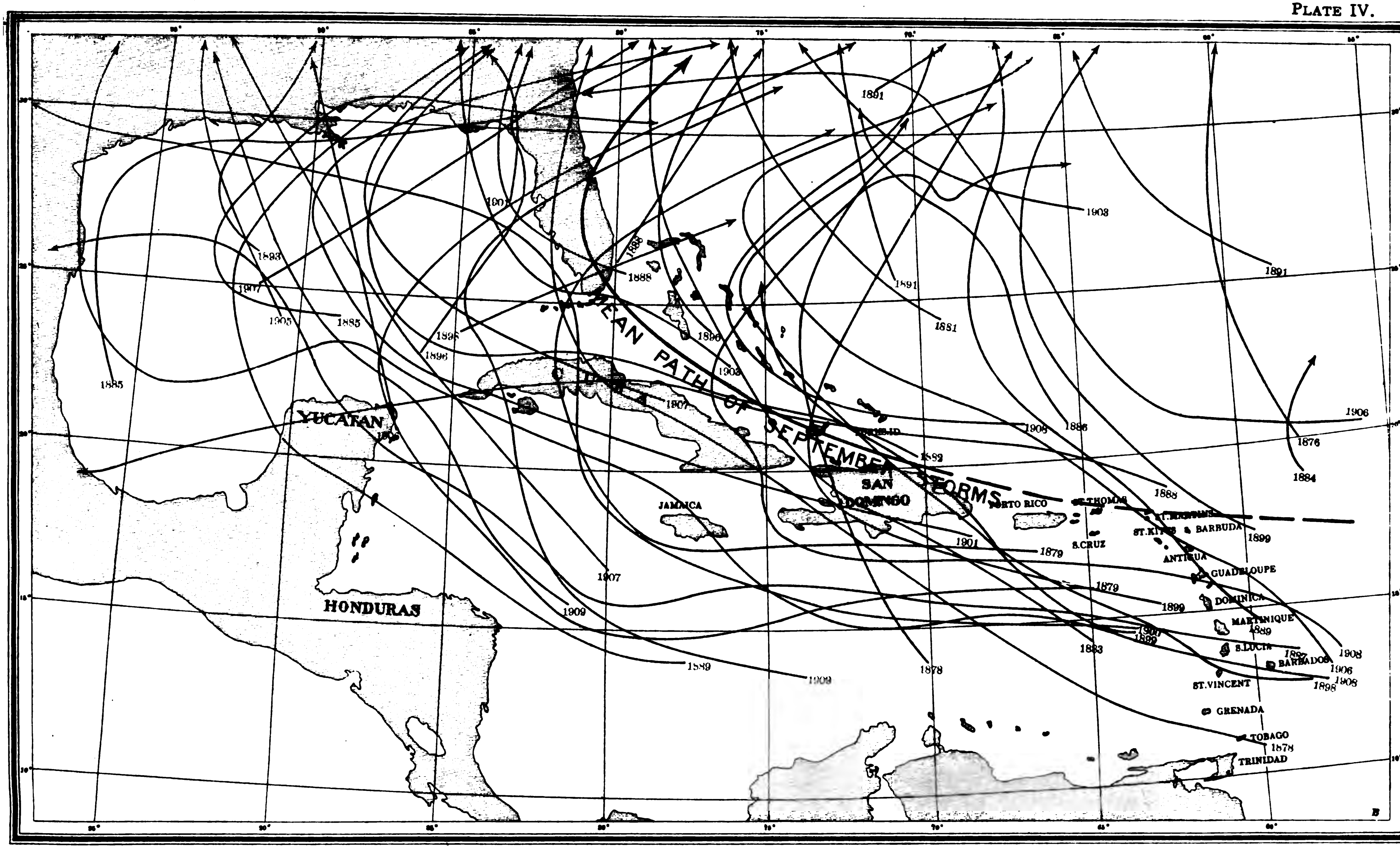
PATHS OF WEST INDIAN HURRICANES DURING JUNE AND JULY FROM 1876 TO 1911.

PLATE III.

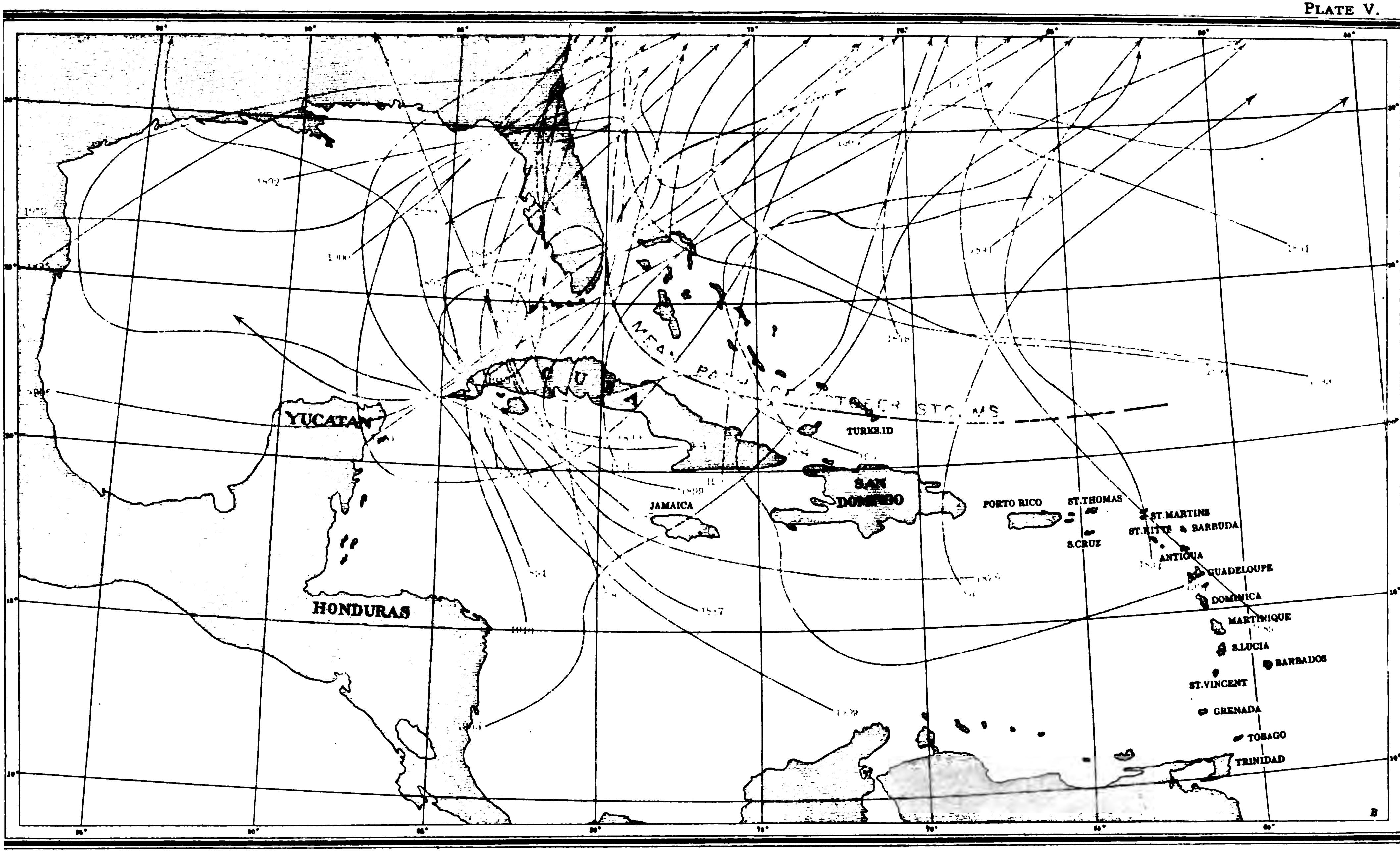


PATHS OF WEST INDIAN HURRICANES DURING AUGUST FROM 1876 TO 1911.

PLATE IX.

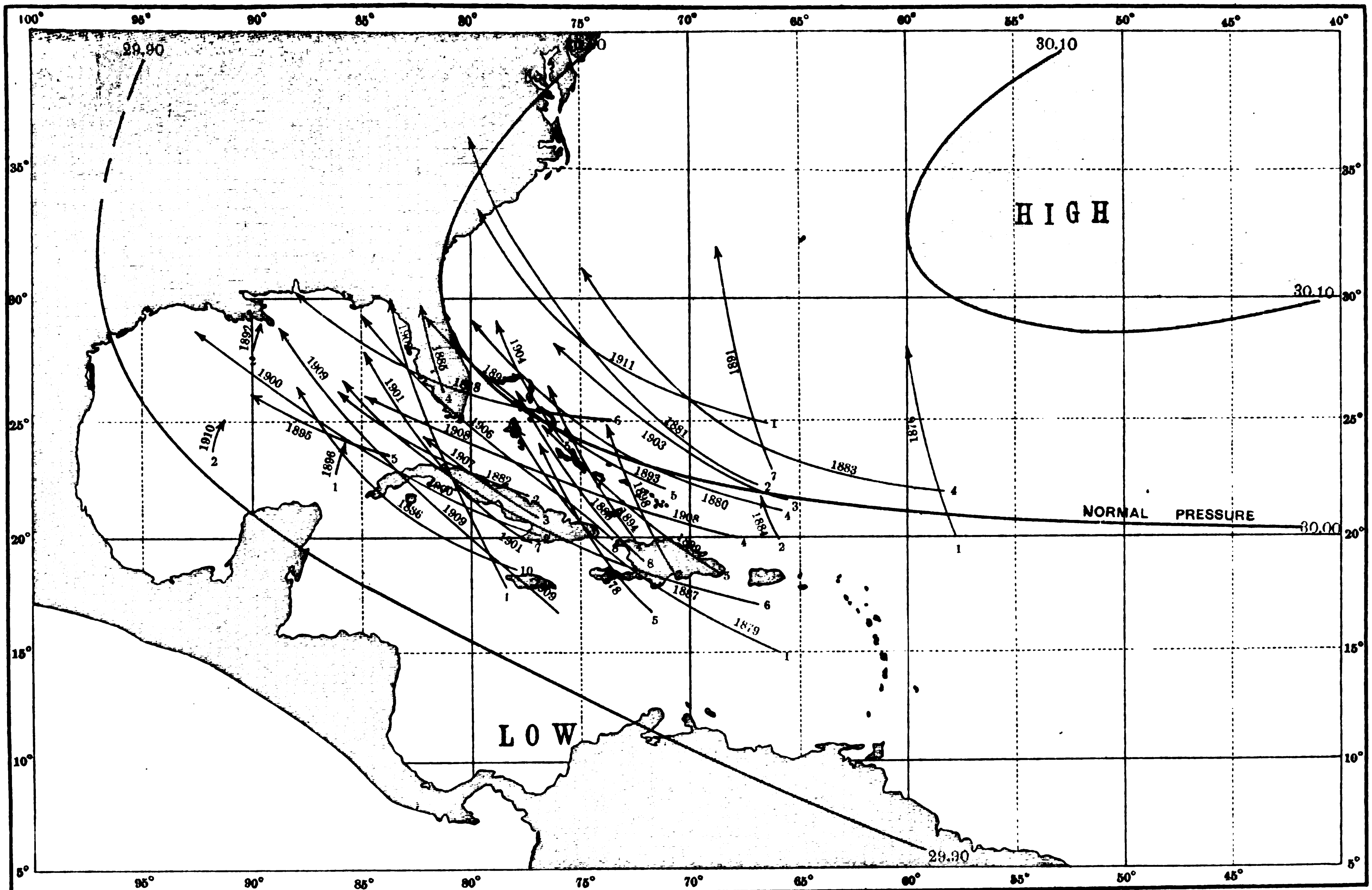


PATHS OF WEST INDIAN HURRICANES DURING SEPTEMBER FROM 1876 TO 1911.



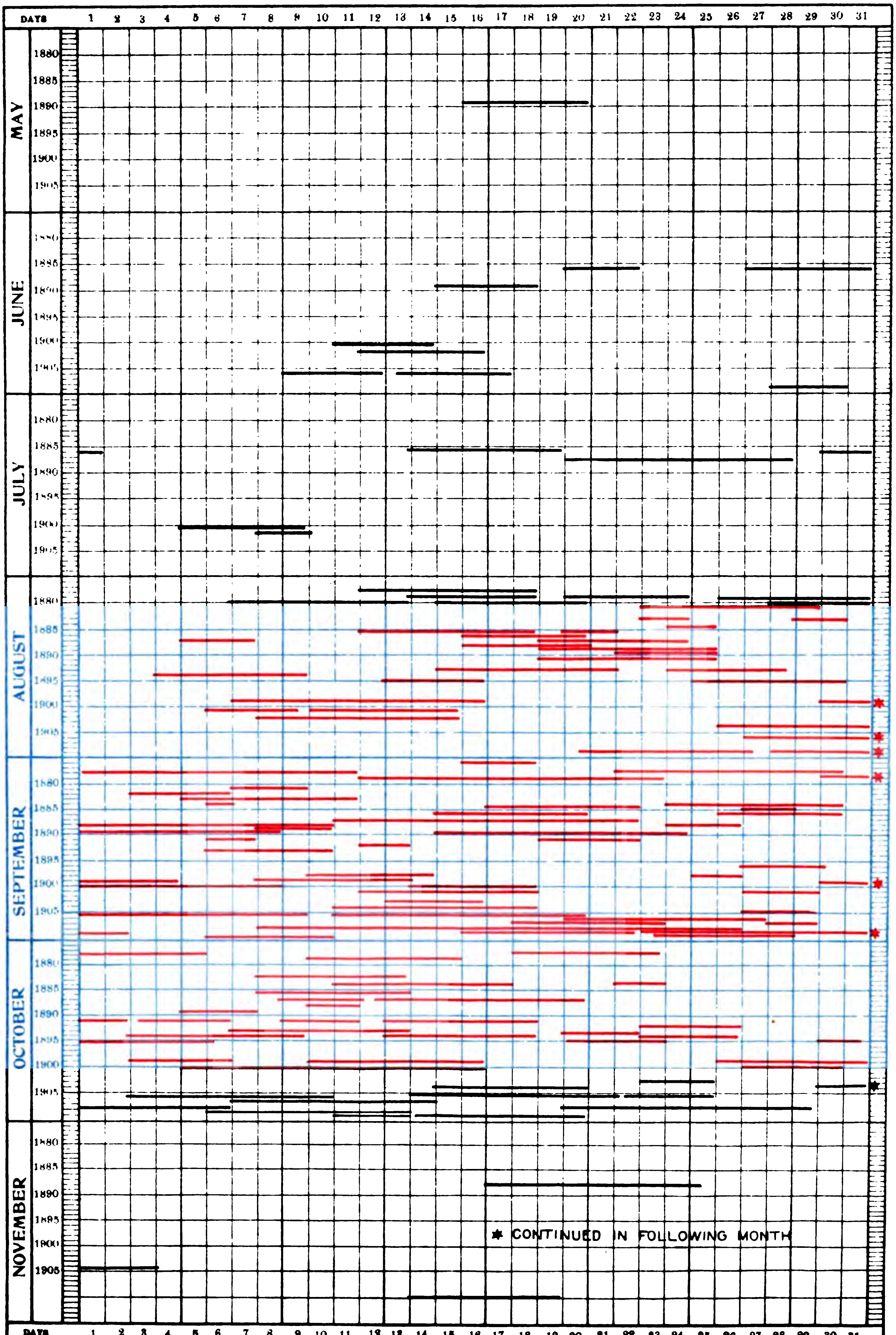
PATHS OF WEST INDIAN HURRICANES DURING OCTOBER FROM 1876 TO 1911.

2.4



MEAN ANNUAL PATHS OF HURRICANES FROM 1876 TO 1910.

[NOTE.—Figures at the lower ends of the arrows indicate the number of storms during the year.]



FREQUENCY AND DURATION OF WEST INDIA HURRICANES FROM 1876 TO 1910.

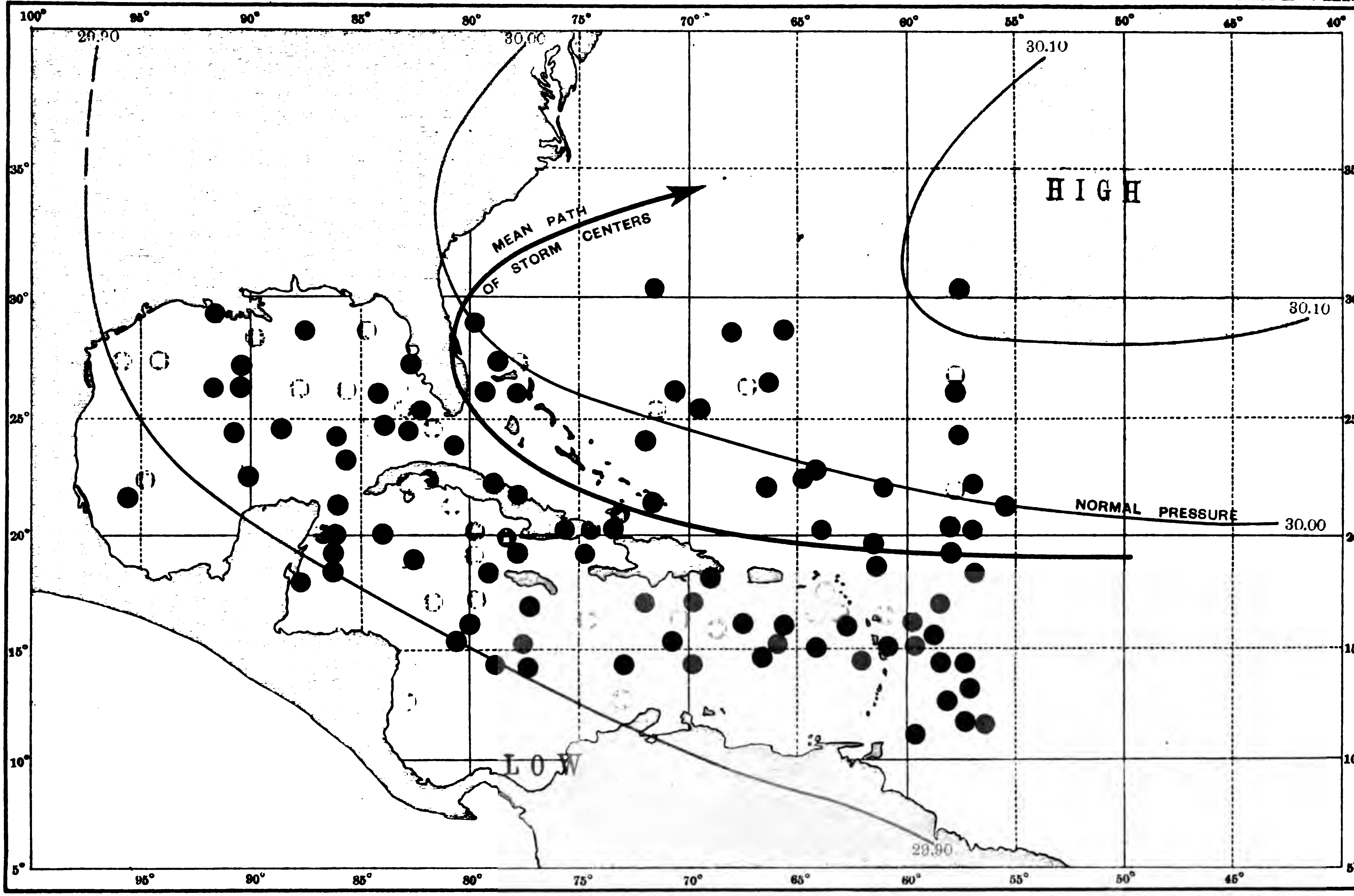
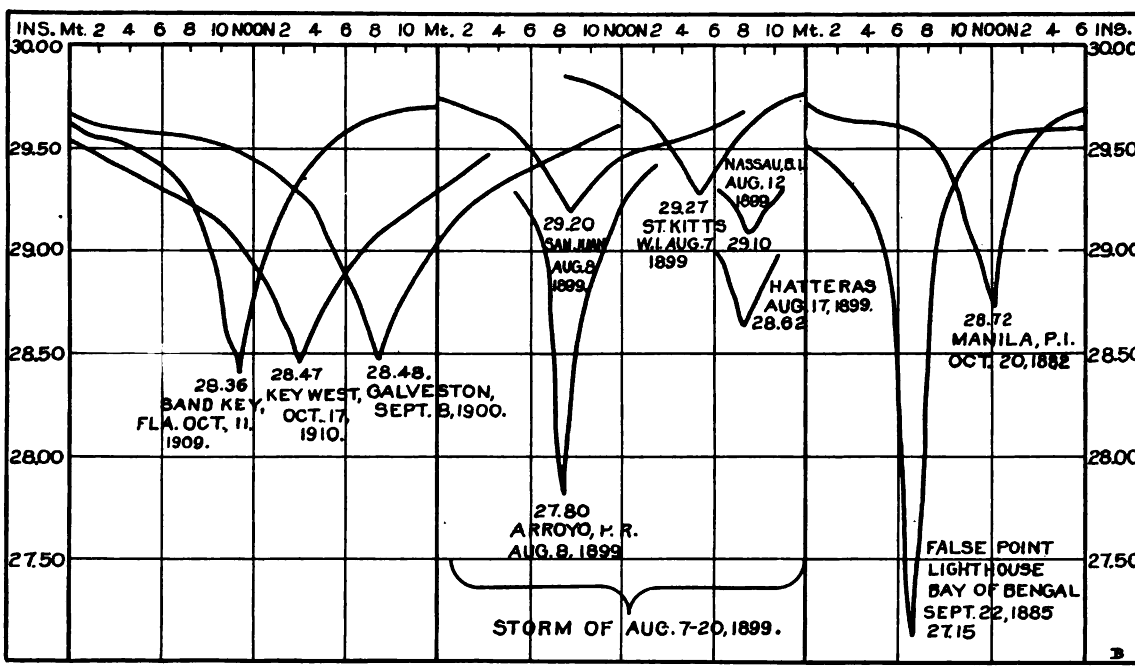


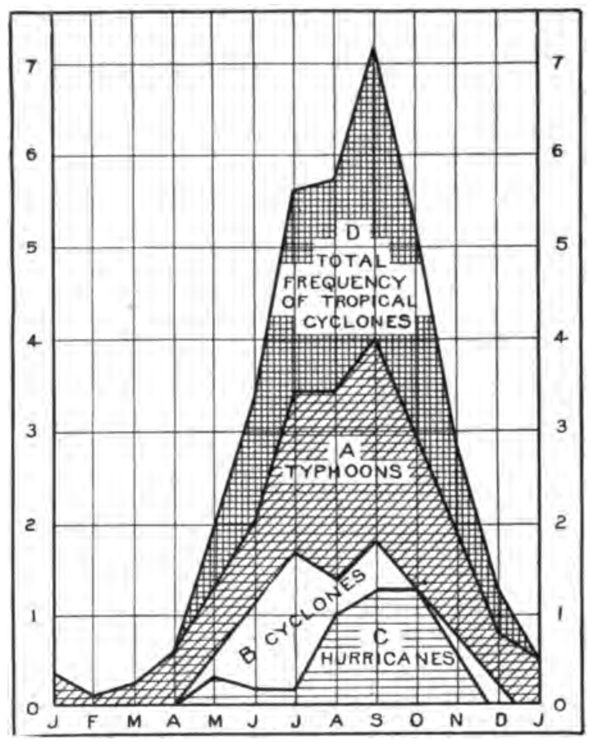
CHART SHOWING THE POINTS OF ORIGIN OF 130 HURRICANES.

BLACK DOTS SHOW ORIGINS OF JUNE AND JULY STORMS.
RED DOTS SHOW ORIGINS OF AUGUST STORMS.
BLUE DOTS SHOW ORIGINS OF SEPTEMBER STORMS.
YELLOW DOTS SHOW ORIGINS OF OCTOBER STORMS.



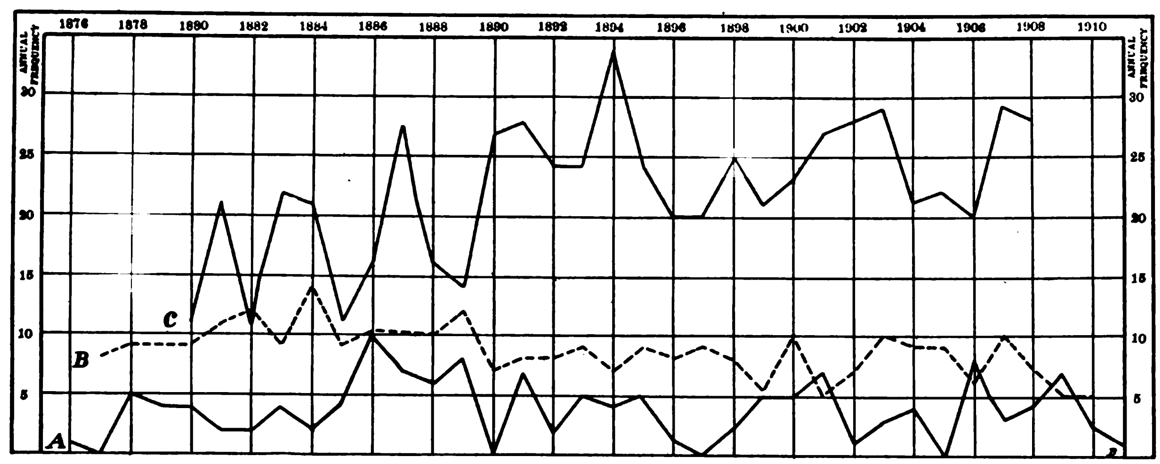
PRESSURE CHANGES DURING TROPICAL CYCLONES.

PLATE X



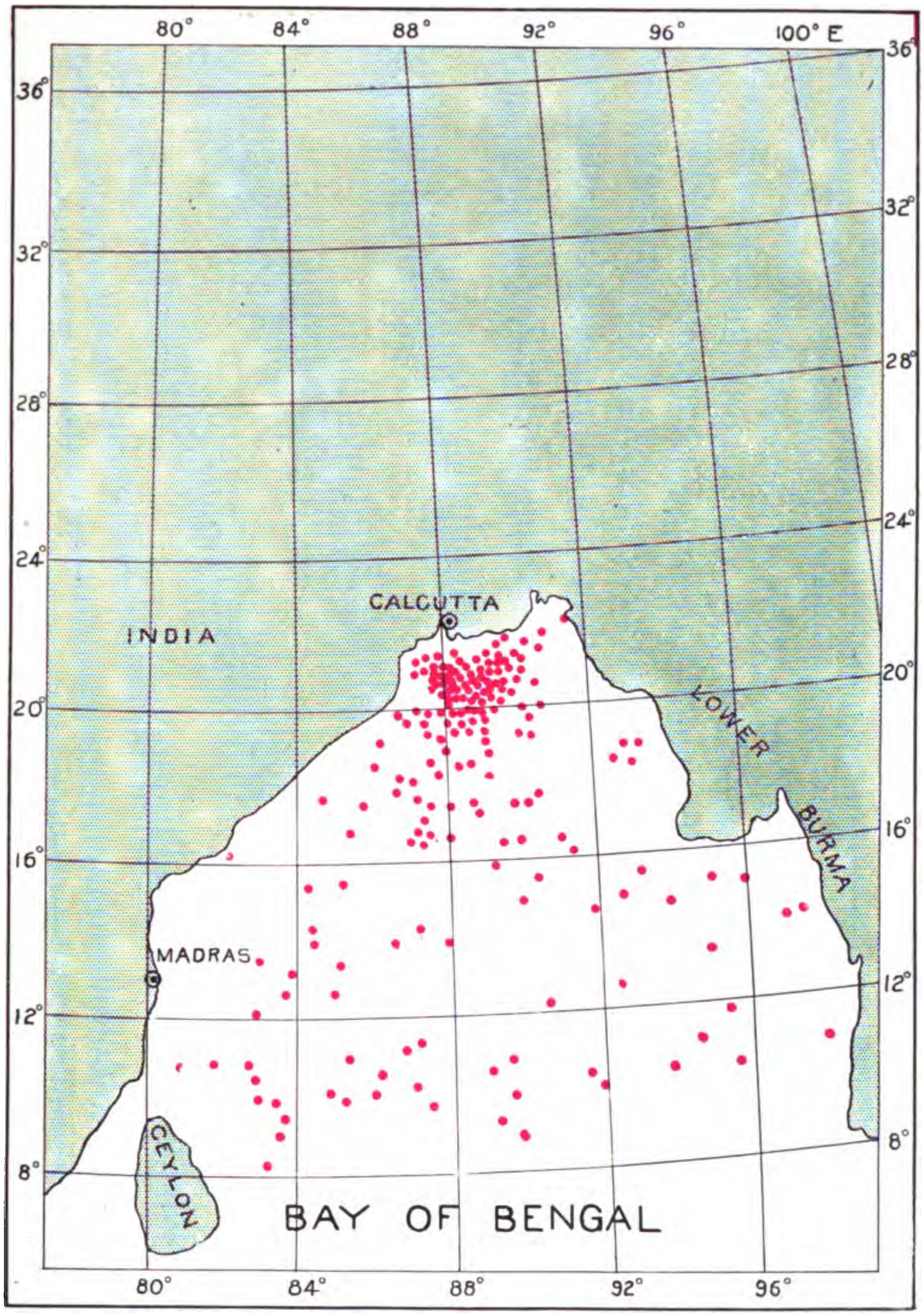
MEAN MONTHLY AND ANNUAL FREQUENCY OF TROPICAL STORMS.

PLATE XI

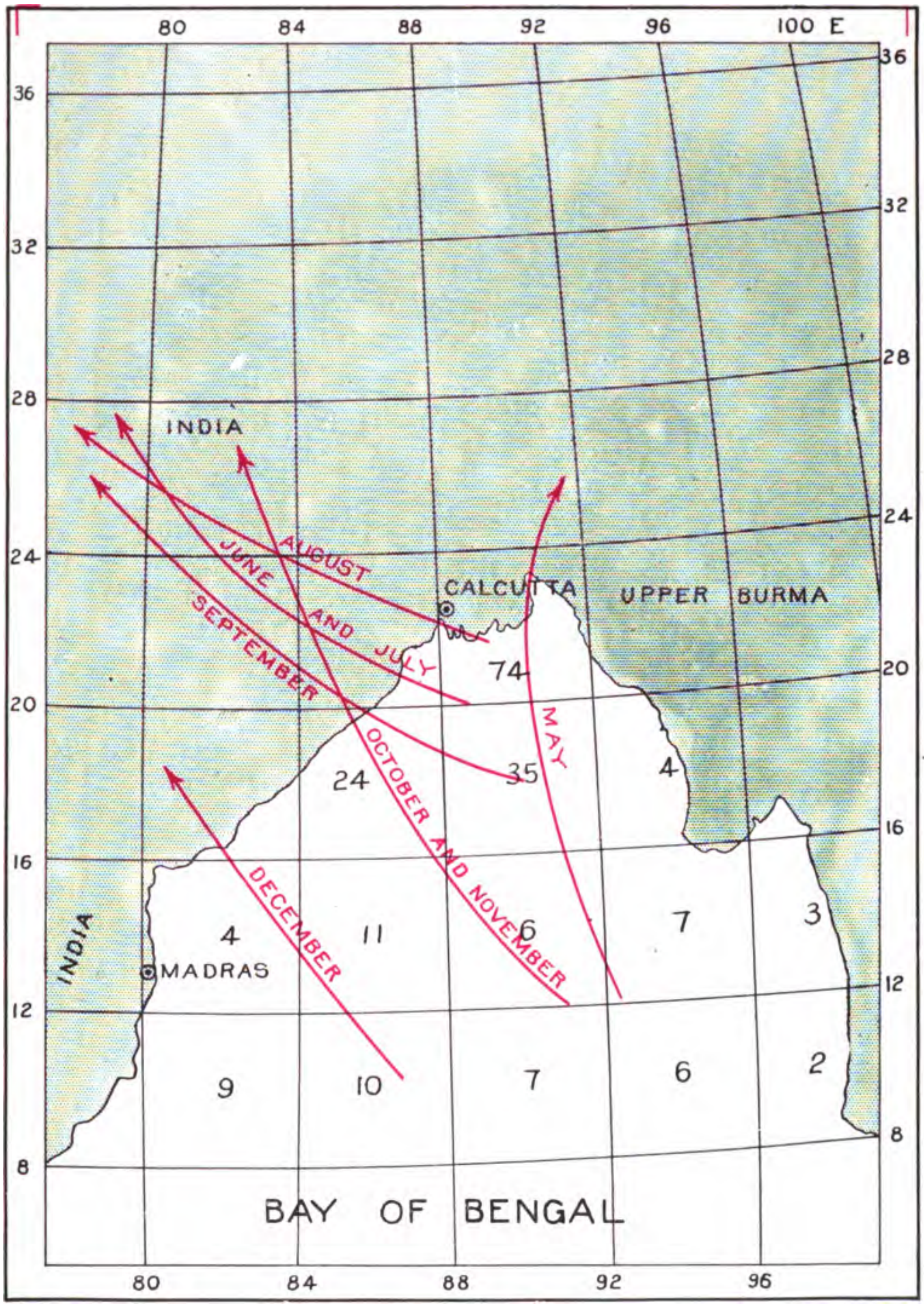


ANNUAL FREQUENCY OF TROPICAL STORMS.

A. Hurricanes of the West Indies. B. Cyclones of the Bay of Bengal. C. Typhoons of the Western Pacific.



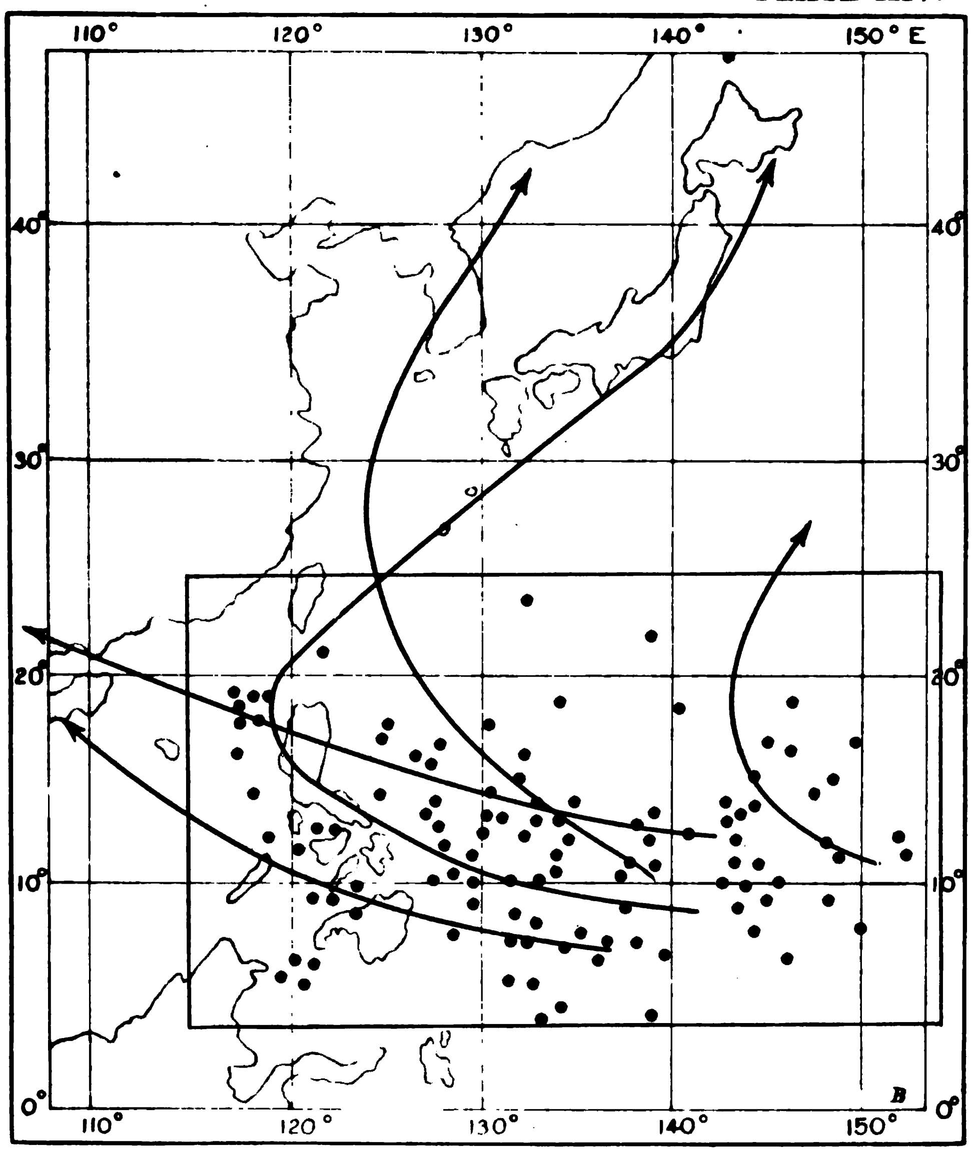
ORIGINS OF CYCLONES IN THE BAY OF BENGAL.



FREQUENCY AND MEAN TRACKS OF CYCLONES IN THE BAY OF BENGAL

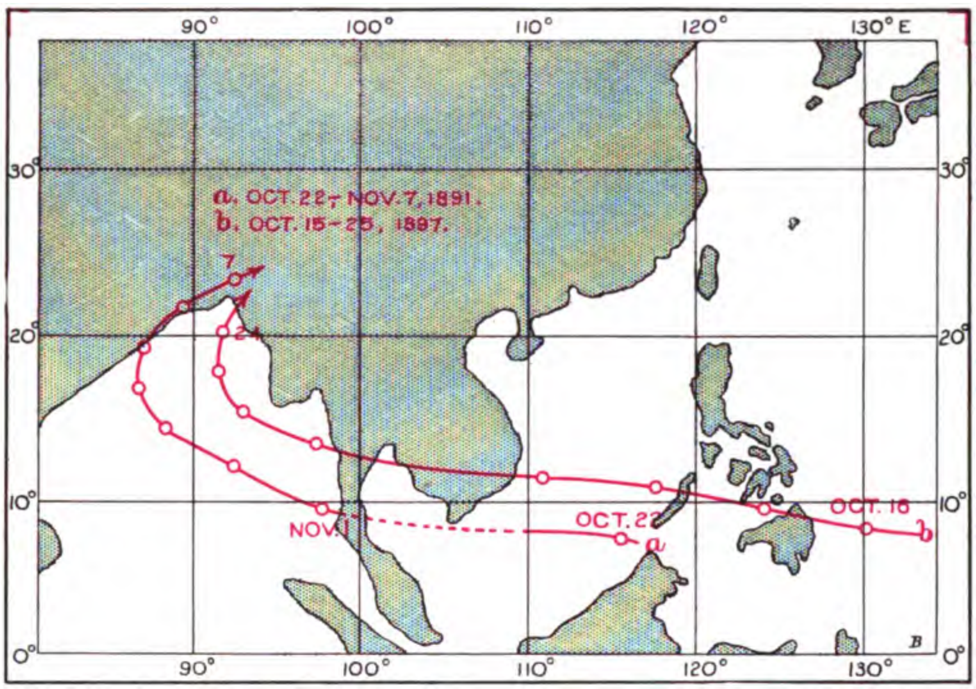
[Frequency shown for each 4 degree square.]

PLATE XIV.

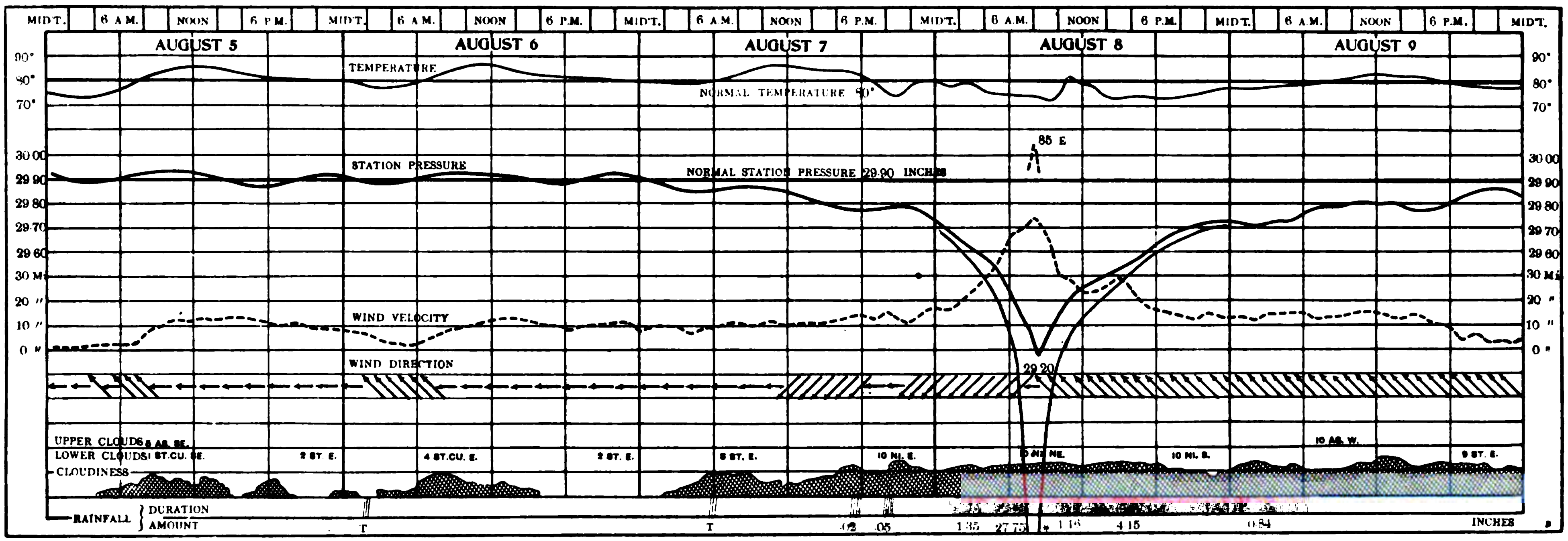


DOTS SHOW POINTS OF ORIGIN OF TYPHOONS OF THE FAR EAST FROM 1880 TO 1902.
LINES SHOW THE MEAN PATHS OF TYPHOONS FROM 1880 TO 1902.

(From Algue: Cyclones of the Far East.)

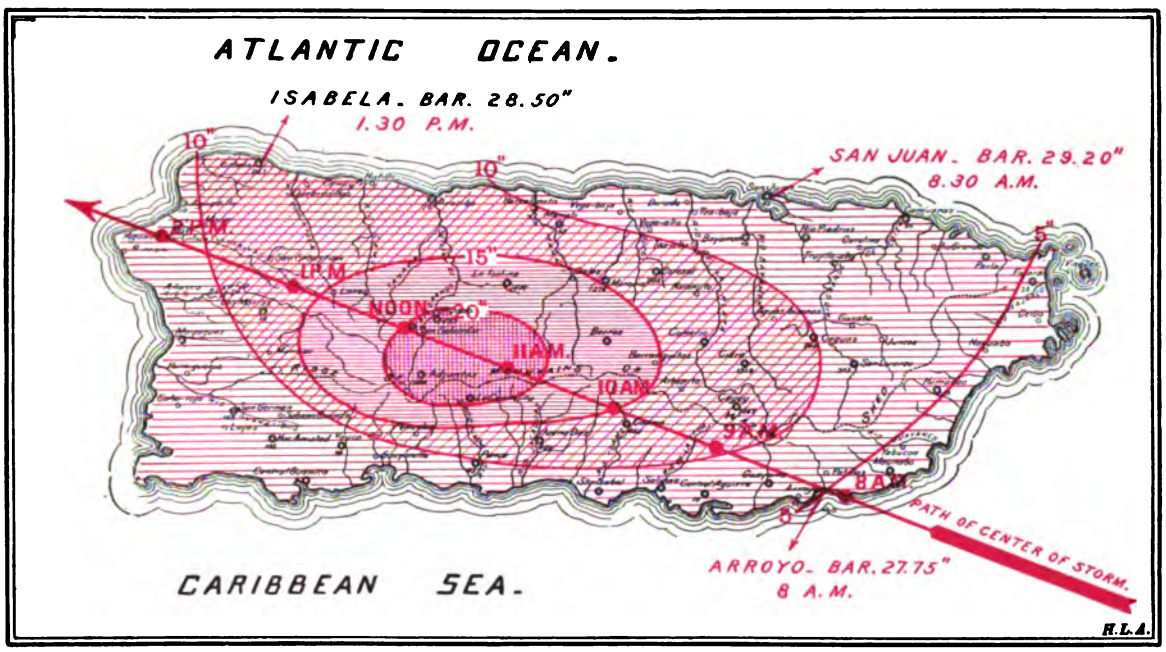


PATHS OF TWO REMARKABLE TYPHOONS.

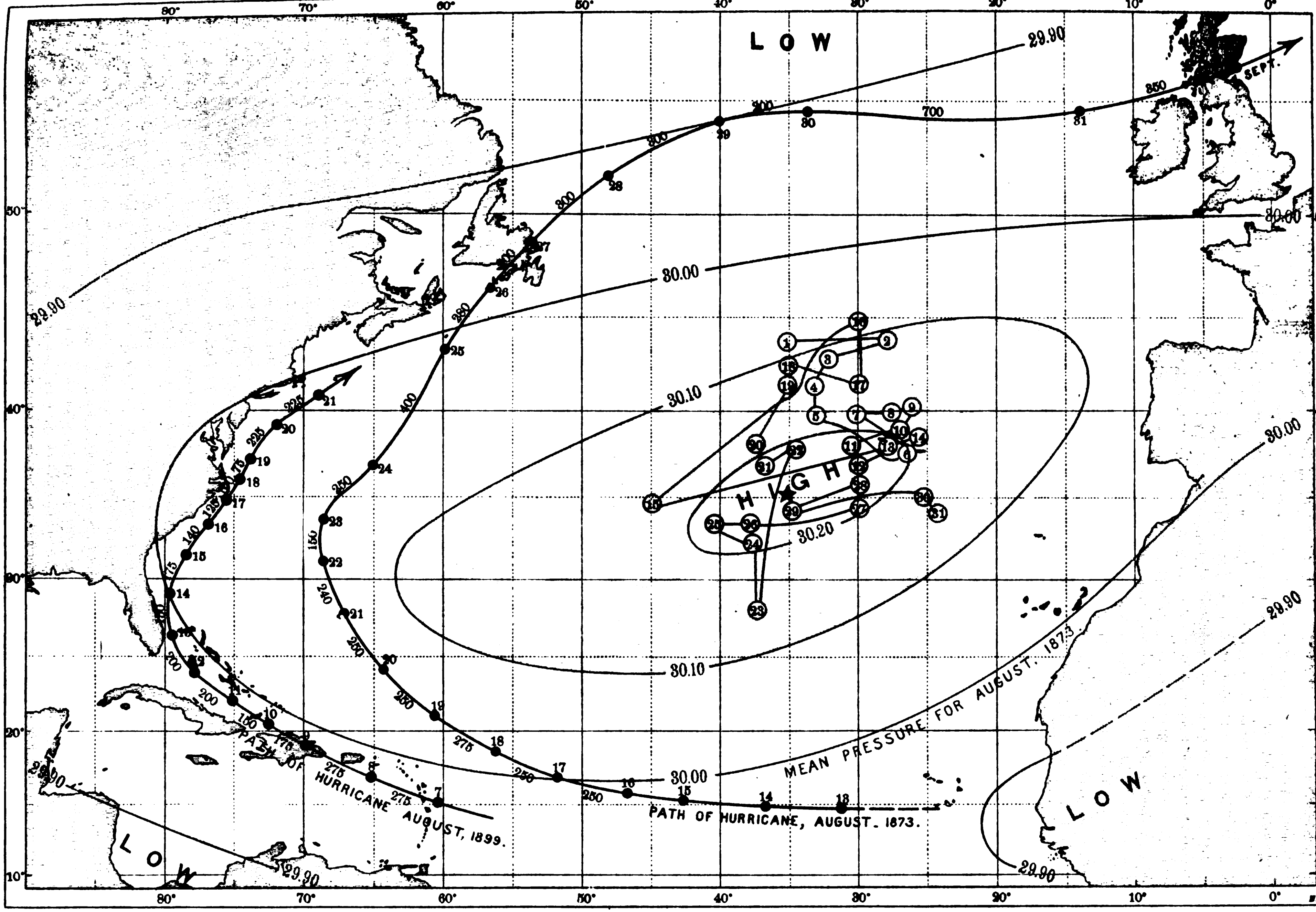


HOURLY OBSERVATIONS AT SAN JUAN, PORTO RICO, DURING THE HURRICANE OF AUGUST 8, 1899.

(CENTER OF STORM OVER PORTO RICO.* BAROMETER READING AT ARROYO, 30 MILES SOUTH OF SAN JUAN, 27.75 INCHES.)

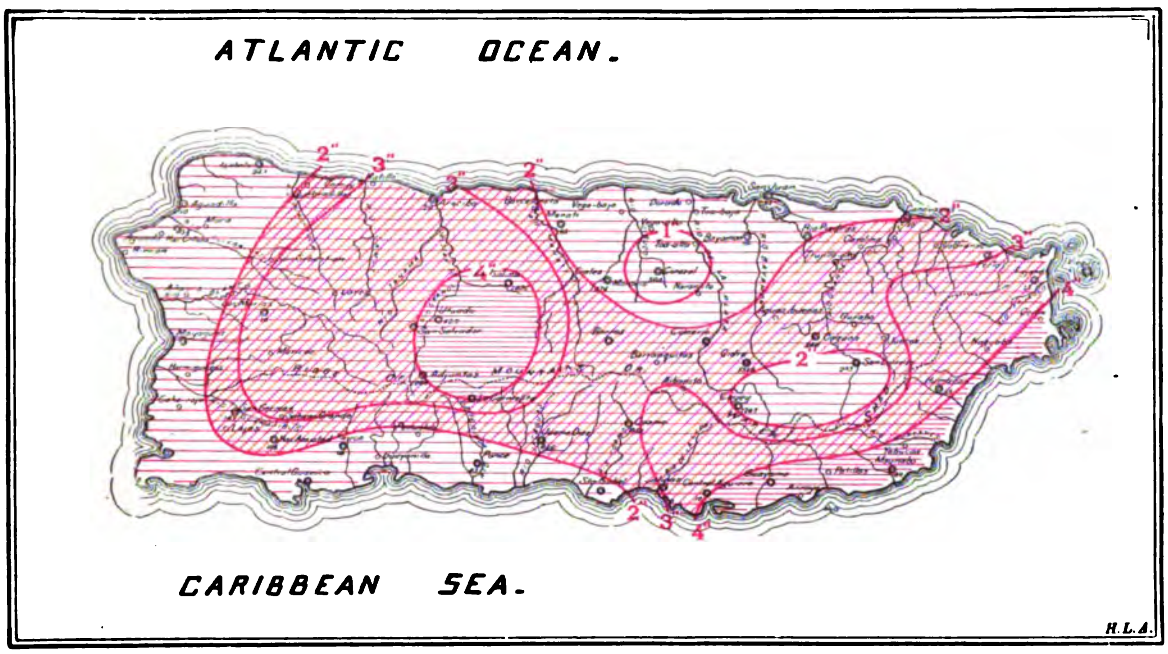


RAINFALL IN PORTO RICO DURING THE HURRICANE OF AUGUST 5-9, 1889.

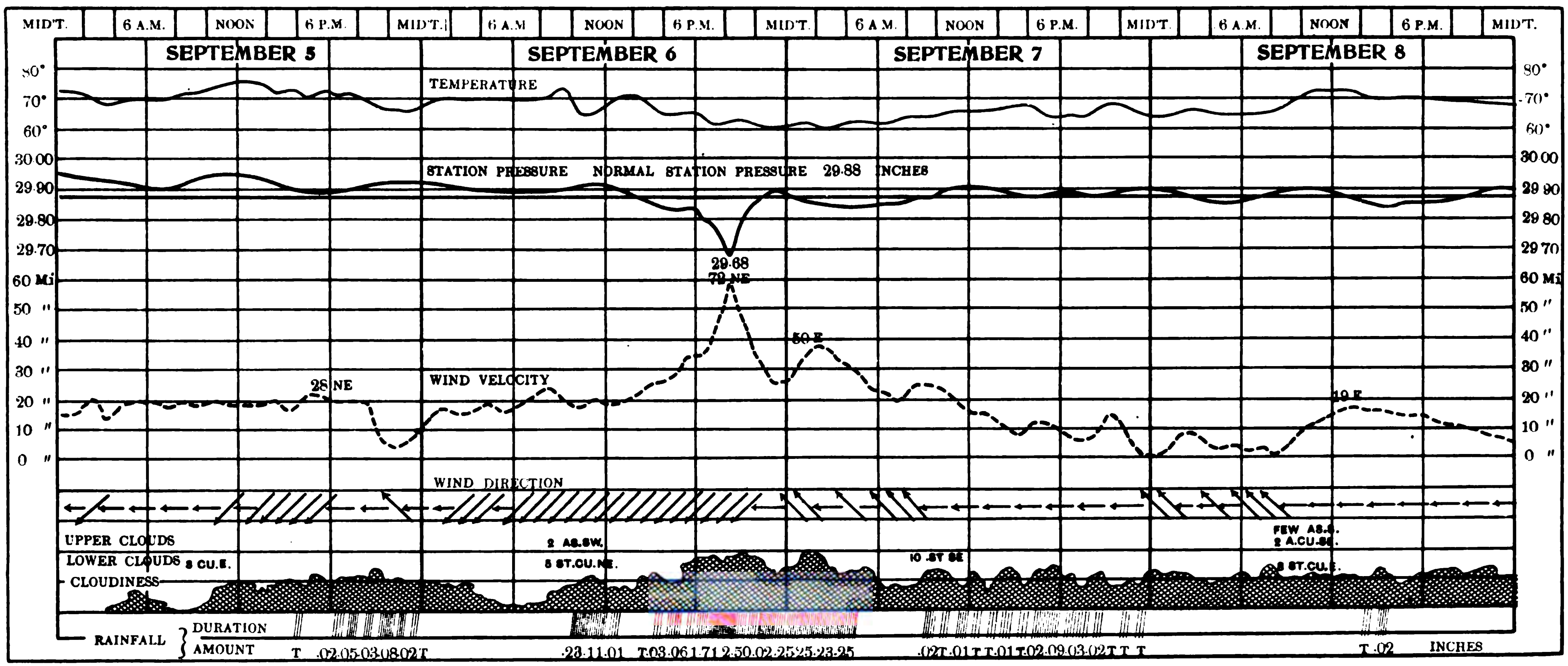


HURRICANE PATHS OF AUGUST 14–31, 1873, AND AUGUST 7–20, 1899, AND THE DISTRIBUTION OF ATMOSPHERIC PRESSURE OVER THE NORTH ATLANTIC.

[NOTE.—The inclosed figures in the central portion of the area of high pressure indicate the position of the area of high pressure from day to day during August, 1873. The blue dots show the daily movement of the storm, in miles.]

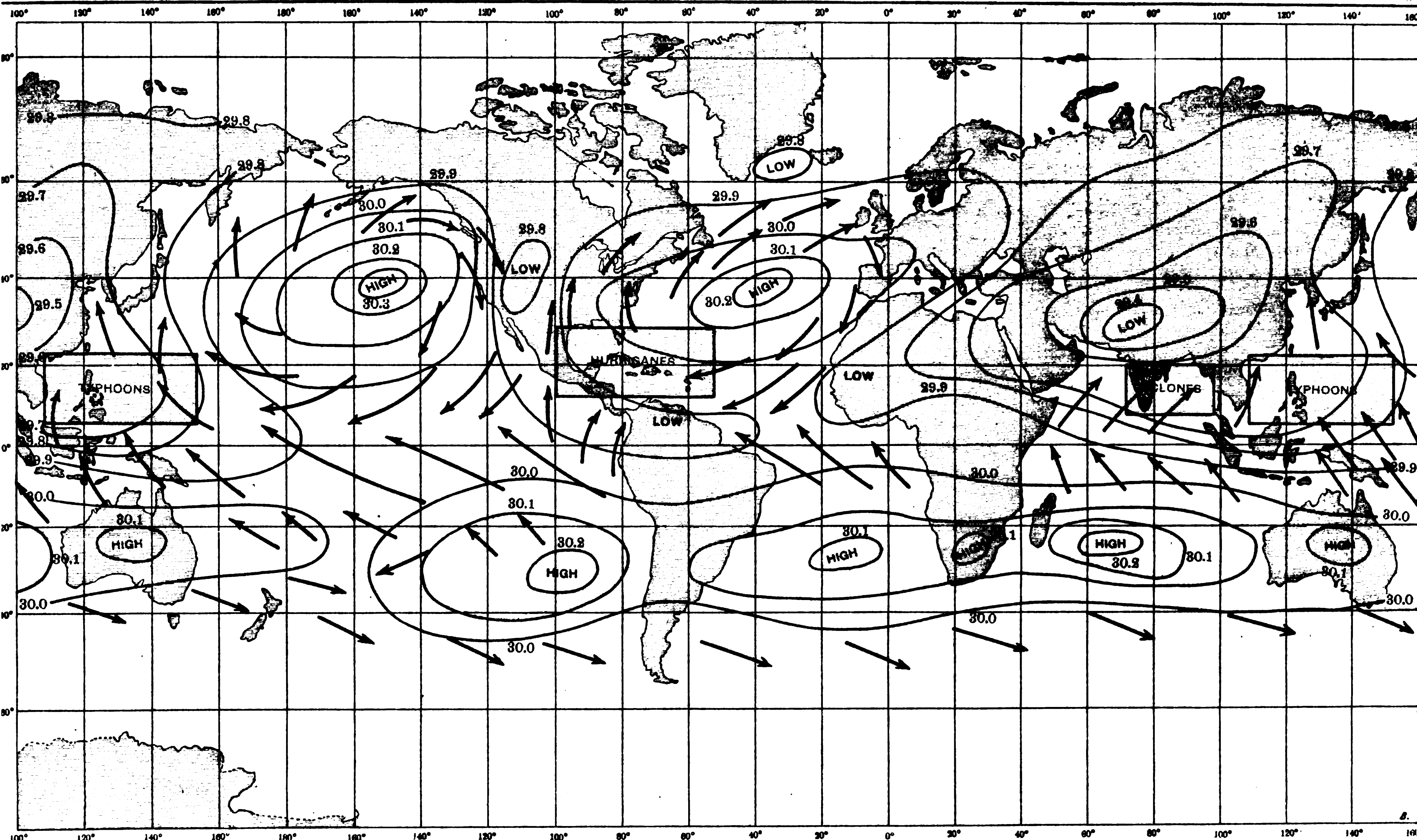


RAINFALL IN PORTO RICO DURING THE HURRICANE OF SEPTEMBER 1-5, 1906.



HOURLY OBSERVATIONS AT SAN JUAN, PORTO RICO, DURING THE LOCAL STORM OF SEPTEMBER 6–7, 1910.

PLATE XXV.



TROPICAL STORM AREAS IN THE NORTHERN HEMISPHERE, AND DISTRIBUTION OF PRESSURE AND PREVAILING WINDS DURING THE HURRICANE SEASON.

W. B. No. [illegible] Issued [illegible]

U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

C. F. MARVIN, Chief

THE OHIO AND MISSISSIPPI FLOODS OF 1912

BULLETIN Y

BY

H. C. FRANKENFIELD

Professor of Meteorology

WASHINGTON

GOVERNMENT PRINTING OFFICE

[illegible]

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU, OFFICE OF THE CHIEF,
Washington, D. C., October 2, 1913.

The honorable the SECRETARY OF AGRICULTURE.

SIR: I have the honor to transmit herewith a report on the Ohio and Mississippi floods of 1912, prepared by H. C. Frankenfield, professor of meteorology, United States Weather Bureau.

I recommend the publication of this report as a bulletin of the Weather Bureau.

Very respectfully,

C. F. MARVIN, *Chief of Bureau.*

Approved.

B. T. GALLOWAY, *Acting Secretary.*

LIST OF ILLUSTRATIONS.

CHARTS.

DIAGRAMS.

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ERRATA.

Delete the words "Part I" on all of the charts and diagrams accompanying this paper.

9

THE OHIO AND MISSISSIPPI FLOODS OF 1912.

By H. C. FRANKENFIELD, *Professor of Meteorology.*

THE DRAINAGE BASIN OF THE MISSISSIPPI RIVER.

A full description of the character and extent of the basin of the Mississippi River will be found in Bulletin E (Weather Bureau, 1897) and in the Annual Report of the Chief of the Weather Bureau, 1896–7, and those who desire more detailed information are referred to these publications. From them it is learned that the great drainage basin of the Mississippi River comprises an area of about 1,240,050 square miles, or about 41 per cent of the total area of the United States, exclusive of Alaska, and extending between the Allegheny and the Rocky Mountains through 56° of longitude and 21° of latitude. There are six grand subdivisions, five of them comprising the watersheds of the largest tributaries, and the names and areas of the six subdivisions are as follows (see chart 1, appendix):

TABLE I.

Designation.	Area in square miles.	Ratio to whole basin.
Ohio Basin	201, 700	0. 16
Upper Mississippi Basin	165, 900	. 13
Missouri Basin	527, 150	. 43
Arkansas Basin	186, 300	. 15
Red Basin	90, 000	. 07
Central Valley	69, 000	. 06
Total	1, 240, 050	1. 00

FLOOD FREQUENCY.

In the Ohio River and in the Mississippi River below Cairo, Ill., years without floods are exceptional, while in the Mississippi River above Cairo stages above the flood line, as measured by the gage heights at St. Louis, Mo., are the exception rather than the rule, occurring on an average about one year in every four or five. Prior to the nineteenth century little is known of the occurrence of floods except through more or less authentic tradition. Of the lower Mississippi floods, the most notable occurred in 1815, 1828, 1844, 1849, 1850, 1851, 1858, 1859, 1862, 1865, 1867, 1874, 1882, 1884, 1890, 1893, 1897, 1903, and 1912, being 19 years in all, or an average of one flood to about each six years. In the upper Mississippi River the years of marked high water, as measured on the St. Louis gage, were 1785, 1811, 1823, 1826, 1844, 1851, 1855, 1858, 1862, 1881, 1883, 1892, 1903, and 1909, being 14 in all, or an average of one flood to about each nine years. The greatest lower Mississippi flood, measured by the flood height, occurred in 1912, while in the upper Mississippi the greatest flood was probably that of 1785, "L'annee des grandes eaux," when the river at St. Louis is said to have reached a stage corresponding to a height of 42 feet

on the present gage, or 0.6 foot higher than the stage of June 28, 1844. However, the stage of 42 feet in 1785 is not one of actual record, but of tradition only, and the flood of 1844 is usually considered to have been the greatest of upper Mississippi and lower Missouri floods.

Causes of Mississippi River Floods.

The normal rains of late winter and early spring over the lower Mississippi Valley are usually sufficient to bring the rivers almost to the flood stage from Cairo to the Gulf of Mexico. Then, if the spring rains over the Ohio Basin are heavier than usual, an enormous volume of water from the main river and the swift-running mountain tributaries is brought down upon the lower Mississippi, already at bank-full stage, and a disastrous flood results. If the winter happened to be a moderately cold one, with plenty of snow laying upon the ground, there would be a further increment from the melted snows, as the spring rains are almost invariably accompanied by high temperatures. Thus the Ohio and the lower Mississippi Rivers alone can produce a great flood, independently of the upper Mississippi and the great western tributaries of the lower river. The upper Mississippi, while in itself incapable of causing a flood in the lower river, yet, rising later than the Ohio, as a rule, serves to prolong the high water and at times to increase somewhat the stages from Cairo southward. Fortunately the lower western tributaries thus far do not appear to have played an important part in flood causation, yet the possibility of simultaneous floods in both the eastern and the western tributaries and in the main stream is ever present; and should this condition arise, the resulting stages between Cairo and the Gulf would probably be higher than have yet been recorded.

It appears that the precipitation that directly causes the Ohio and Mississippi floods is due to a single type of storm known as "The Southwest" type, for the reason that usually it is first observed in definite formation over the southwestern portion of the country. These storms move in from the Pacific Ocean, the majority of them by way of the north coast, whence they move southeastward through the great plateau until they reach western Texas, when they turn northeastward over the Ohio Valley and the Lake region with increased development and velocity of movement, accompanied by heavy rains and high temperatures over the Gulf States and the Ohio Valley, and frequently by snow to the northward. A small portion moves inland by way of California, and a still smaller portion by way of Mexico, but, with rare exceptions, all reach Texas and move northeastward as indicated above. None appears to develop true storm conditions until Texas is reached, and about 95 per cent of them are preceded and accompanied by heavy rains and high temperatures to the eastward and southeastward, and by rains and snows to the northward. If the temperatures to the northward range between 25 and 32° F. the snowfall will be heavy, both as to quantity and character. Flood probability depends upon the number and time of occurrence of these southwest storms, and, of course, somewhat upon the antecedent conditions. The storms usually begin in February and continue during March and at times a portion of April. If the early winter has been a cold one, resulting in a frozen soil and the accumulation of a considerable amount of snow over the Ohio watershed, the flood probability will be increased. If there should be but a single storm, or even if there should be several storms separated by considerable intervals of time, the flood wave will be short and the river stages only moderately high, but if there should be a series of storms, separated by intervals of only a few days, as in the present year, a severe flood is certain, and its intensity will be limited only by the amount of precipitation, which in any event is almost certain to be heavy. The accumulated snowfall will usually go out with the first storm, and, if the early winter has been cold, the run-off from the first one or two storms will obviously be greater than the normal run-off. The normal winter and spring rainfall over the Gulf States is comparatively heavy and any considerable increase in the amount, if distributed over an extended period of time, will bring the lower Mississippi and the Yazoo Rivers to stages above the flood line and while in this condition the extensive flood wave from the Ohio pours in, provided the direction of storm movement has been about normal. If, by any chance,

the storm centers, or any number of them, should pass to the southward of the Ohio Valley, the precipitation over that district would be much less in quantity and the temperature would be much lower, thereby preventing the melting of any considerable quantity of the snow that might be on the ground. Consequently the lower Mississippi flood would pass into the Gulf of Mexico without unusual incident unless additional heavy rains should bring the western tributaries to very high stages—a comparatively infrequent occurrence and one not of any considerable moment so far as the lower river itself is concerned—as the Ohio River is the principal factor in the question.

The Flood of 1912.

The annual rise of the lower Mississippi River for the year 1912 began on February 21, at which time a severe storm from the Southwest was moving northeastward over the lower Mississippi and the Ohio Valleys, attended by general and heavy rains. A second storm of similar character moved northeastward four days later, and the rise was well under way in the lower Ohio River and in the lower Mississippi between Cairo and the mouth of the Arkansas River. By the end of February the Ohio River was above the flood stage from Evansville, Ind., to Shawneetown, Ill., while the Mississippi was rising rapidly as far south as the mouth of the Red River, and had nearly reached the flood stage of 34 feet at New Madrid, Mo. The winter had been a cold one, without much snow over that portion of the Ohio watershed where it would have remained on the ground for any considerable period after it had fallen, and it so happened that on February 26 there was no accumulated snowfall over any portion of the Ohio River watershed except a negligible quantity over central and southern Indiana and southeastern Illinois. There were no heavy rainstorms probable in the near future, and consequently no immediate fears of a great flood. While rains and snows were comparatively frequent during the first decade of March, they were not heavy, and after March 4 the Ohio River at Cairo began to fall after reaching a stage of 41.8 feet, 3.2 feet below the flood stage. Shortly afterwards the Mississippi River began to fall at New Madrid and the fall continued for about 10 days, but did not extend below the mouth of the Arkansas River, as the occasional rains were sufficient to maintain the original rise from above. On March 10 an extensive barometric depression moved in from the Pacific Ocean to southern California, and by the following morning it had reached Kansas, with a secondary storm center reaching down over southeastern Texas. During the day (March 11) the general disturbance moved eastward and northeastward over the normal path of southwestern storms, and moderately heavy rains, averaging less than 1.5 inch, fell over Louisiana and Mississippi. Over the Ohio Basin the rains, while well distributed, were not heavy, and some light snow fell, the quantity being just about sufficient to maintain the average depth of from 1 to 3 inches that had covered that portion of the Ohio watershed north of Tennessee since the earliest days of March. While this storm was moving across the country another appeared on the north Pacific coast. It moved southeastward over the districts west of the Rocky Mountains, and by the time (March 14) that the preceding storm had passed off the Newfoundland coast, the second one had moved to Kansas, accompanied, like its immediate predecessor, by a secondary depression extending southward over southeastern Texas. During the succeeding 24 hours rains again fell over Louisiana and Mississippi and extended into the lower Ohio Valley, with lighter rains above. The heaviest rains fell over the Yazoo Valley, but the quantity was not excessive. The rains did not continue for more than 24 hours, as a rule, but they were sufficient to take out the little snow that covered the Ohio watershed and to augment a rise in the upper Ohio River that had set in after the rains from the preceding storm, and also to start another rise in the lower Ohio and in the Mississippi from Cairo to New Madrid. At the same time the Missouri River east of Kansas City and the Mississippi from Alton, Ill., to Cairo began to rise. This second storm passed into the north Atlantic Ocean during the night of March 15–16, and during the next four days there was no precipitation of consequence over the Ohio and lower Mississippi watersheds. On the morning

of March 19 a disturbance was central over Utah, and at this time some of the river stages were as follows:

TABLE II.—*River stages, Mar. 19, 1912.*

Station.	River.	Flood stage.	Stage, Mar. 19.
		Feet.	*Feet.*
Cincinnati, Ohio	Ohio	50	46.6
Evansville, Ind	do	35	37.2
Nashville, Tenn	Cumberland	40	37.9
Johnsonville, Tenn	Tennessee	25	26.8
Paducah, Ky	Ohio	43	36.1
Cairo, Ill	do	45	40.4
Kansas City, Mo	Missouri	22	8.9
Hannibal, Mo	Mississippi	13	6.2
St. Louis, Mo	do	30	18.7
New Madrid, Mo	do	34	31.6
Memphis, Tenn	do	33	29.2
Helena, Ark	do	42	37.4

At Helena the second rise of the month was just about to begin.

The Utah depression, the third storm of the month, moved over the Ohio Valley by way of Oklahoma and Arkansas, somewhat to the northward of its immediate predecessors, with moderate rains and snows above Cairo, but with little or none below. The precipitation from this storm apparently had no effect other than to check the decline in the upper Ohio River, and the storm center passed into the north Atlantic Ocean during the night of March 21–22. However, another storm had appeared over Arizona, and an offshoot from it traversed the usual path over Texas, reaching the Ohio Valley on the morning of March 24, when the Missouri River east of Kansas City, the Mississippi from Alton to New Orleans, and the Ohio, Cumberland, Tennessee, and Wabash Rivers were rising steadily. The rainfall resulting from this fourth storm was the heaviest of the month, beginning on March 22 over Louisiana and southern Mississippi and extending northward and eastward during the two following days with an average fall of 2.5 inches over the lower Mississippi Valley and somewhat less over the Ohio Valley. At the same time a heavy blanket of moist snow was deposited over Missouri and Kansas, with an average water equivalent of over 1 inch. There was also some snow, probably sufficient to make one-half inch of water, over the northern portion of the Ohio River watershed. As the soil was deeply frozen after the long and cold winter, this large snowfall was equivalent to another heavy rain, and it must necessarily run into the rivers as soon as the temperatures rose to normal conditions or another rainstorm came. Should the high temperatures and the rain come coincidently, as they do during southwestern storms, conditions would become still more threatening. There were no longer any doubts that a severe flood would occur. The only question was as to the final outcome which was now entirely dependent upon the contingency of additional heavy rains in the near future. If there should be more the flood heights must certainly prove to be the greatest of record from Cairo to the Passes should the levees remain intact.

The suspense was not prolonged, for on March 26, one day after the fourth storm moved into the Atlantic Ocean, the fifth one appeared over Nevada. The river stages at various places and the changes in one week from Helena northward, due to the third and fourth storms, were as follows:

TABLE III.—*River stages, Mar. 26, 1912.*

Station.	River.	Flood stage.	Stage Mar. 26.	Change one week.
		Feet.	*Feet.*	*Feet.*
Cincinnati, Ohio	Ohio	50	52.2	+ 5.6
Evansville, Ind	do	35	41.0	+ 3.8
Nashville, Tenn	Cumberland	40	27.6	−10.3
Johnsonville, Tenn	Tennessee	25	29.2	+ 2.4
Paducah, Ky	Ohio	43	43.3	+ 7.2
Cairo, Ill	do	45	49.2	+ 8.8
Kansas City, Mo	Missouri	22	13.8	+ 4.9
Hannibal, Mo	Mississippi	13	10.0	+ 3.8
St. Louis, Mo	do	30	24.7	+ 6.0
New Madrid, Mo	do	34	38.8	+ 7.2
Memphis, Tenn	do	33	35.3	+ 6.1
Helena, Ark	do	42	42.0	+ 4.6
Little Rock, Ark	Arkansas	23	14.0	+ 1.4
Arkansas City, Ark	Mississippi	47	45.5	+ 1.3
Yazoo City, Miss	Yazoo	25	23.8	+ 1.0
Vicksburg, Miss	Mississippi	45	43.0	+ 1.1
Natchez, Miss	do	46	42.6	+ 1.5
Alexandria, La	Red	36	22.7	+ 0.1
Baton Rouge, La	Mississippi	35	31.3	+ 1.0
Donaldsonville, La	do	28	24.7	+ 0.8
New Orleans, La	do	18	15.4	+ 0.2
Monroe, La	Ouachita	40	35.9	+ 4.4
Simmesport, La	Atchafalaya	41	36.0	+ 1.7
Melville, La	do	37	36.1	+ 1.2

Owing to stagnant pressure conditions in the extreme West, the fifth storm did not reach Texas until the morning of March 28, when rains were falling over the great central valleys. Approximately 1 inch of rain fell, with the greatest fall below Cairo; and the storm also melted and brought out the heavy, moist snow that had fallen during the preceding storm, so that the run-off was practically doubled. It was now certain that, should the levees hold, all previous high-water records from Cairo to Memphis would be exceeded, and equally certain that another heavy rain would result in similar conditions from Memphis south to the mouth of the river. Again the period of suspense was short, for on the evening of March 29 another disturbance, the sixth and last of the remarkable series, was central over Utah. It moved more slowly than its predecessors and did not reach eastern Texas until the morning of April 1, moving then to the northeastward over the Ohio Valley. It happened, unfortunately, that the rains from this storm were heaviest over those sections where they were least desired. Over Louisiana and southern Mississippi, where another inch or so of rain would not have changed conditions materially, the rainfall was light, while to the northward almost as far as St. Louis and to the eastward over Tennessee and Kentucky it was heavy, especially over eastern Arkansas and the Yazoo Valley. As a result the rate of rise in the lower Ohio and the lower Mississippi was maintained or increased, the Cumberland passed the flood stage, the Tennessee rose more rapidly, while the Missouri east of Kansas City, the Mississippi from Hannibal to Cairo, the lower Arkansas, the White and the Black Rivers also passed the flood stage. There could be no further doubt, and warnings were issued that the coming flood heights from Cairo to the

Gulf of Mexico would be the greatest in history. The stages at this time and the changes in one week were as follows:

TABLE IV.—*River stages, Apr. 2, 1912.*

Station.	River.	Flood stage.	Stage Apr. 2.	Change one week.
		Feet.	*Feet.*	*Feet.*
Cincinnati, Ohio	Ohio	50	46.8	− 5.4
Evansville, Ind	....do	35	42.3	+ 1.3
Nashville, Tenn	Cumberland	40	41.8	+14.2
Johnsonville, Tenn	Tennessee	25	31.6	+ 2.4
Paducah, Ky	Ohio	43	47.8	+ 4.5
Cairo, Ill	....do	45	53.5	+ 4.3
Kansas City, Mo	Missouri	22	23.1	+ 9.3
Hannibal, Mo	Mississippi	13	14.8	+ 4.8
St. Louis, Mo	....do	30	29.8	+ 5.1
New Madrid, Mo	....do	34	42.3	+ 3.5
Memphis, Tenn	....do	33	41.9	+ 6.6
Helena, Ark	....do	42	48.9	+ 6.9
Little Rock, Ark	Arkansas	23	21.4	+ 7.4
Arkansas City, Ark	Mississippi	47	50.2	+ 4.7
Yazoo City, Miss	Yazoo	25	25.3	+ 1.5
Vicksburg, Miss	Mississippi	45	46.1	+ 3.1
Natchez, Miss	....do	46	44.8	+ 2.2
Alexandria, La	Red	36	29.0	+ 6.3
Baton Rouge, La	Mississippi	35	32.9	+ 1.6
Donaldsonville, La	....do	28	26.0	+ 1.3
New Orleans, La	....do	18	16.7	+ 1.3
Monroe, La	Ouachita	40	39.6	+ 3.7
Simmesport, La	Atchafalaya	41	38.0	+ 2.0
Melville, La	....do	37	37.4	+ 1.3

The rains continued during April and May with more or less frequency, and at times they were heavy, but they do not appear to have done more in the main stream than to prolong the high-water period, as in most instances the loss of water through the crevasses more than offset the effects of the rains. An exception was noted at New Orleans, where during the evening of May 10 nearly 7 inches of rain fell, forcing the river up to the remarkably high stage of 22 feet, or 4 feet above the flood stage, a few hours later. High southerly winds, however, were an important factor in causing this stage, and a decline to the actual high-water level followed shortly afterwards.

Among the appendices to this report will be found copies of the United States Weather Bureau charts (Nos. 2 to 7, inclusive) showing the storms directly contributory to the flood, and also copies of the Weekly Snow Charts (Nos. 8 to 11, inclusive) showing the depth of snow on the ground at different times during the flood.

DURATION OF THE FLOOD.

As the Ohio River at Evansville, Ind., reached the flood stage of 35 feet on March 18, the flood may be considered to have begun on that day. The Mississippi River at New Orleans, La., fell below the flood stage of 18 feet on June 8, and this day may be considered to have been the last day. This would make the total duration of the flood 83 days. In the Atchafalaya River the flood lasted until June 19, on which day the river at Melville, La., fell below the flood stage of 37 feet. Flood stages in this river, however, were not recorded until April 9, when the stage of 41 feet was first reached at Simmesport, La., making the flood duration 72 days. The Yazoo River was in flood for 75 days, beginning on April 1 and ending June 14, while the lower Ouachita River was in flood for 62 days, beginning on April 4 and ending on June 4 at Monroe, La.

The first rise began on February 21 with the advent of a typical southwestern storm, but early in March it was followed by a decline that continued for a week or 10 days as far south as Helena, Ark. Below the mouth of the Arkansas River the initial rise was practically unin-

terrupted. The duration of the flood was materially increased by some abnormally heavy rains that fell over the entire watershed east of Kansas City during the last few days of April. These rains sent a second flood wave down the river, with resulting secondary crests only 0.5 foot below the original one at St. Louis, but 5 to 6 feet lower from Cairo to the mouth of the St. Francis River. From Helena southward the effects consisted only of a considerable prolongation of the original flood wave. The hydrographs (Diagram III, appendix) show the actual conditions that prevailed from March 1 to June 10, inclusive. Hydrographs of the floods of 1882, 1897, and 1903 are also shown. (Diagrams IV, V, and VI.) From these hydrographs it will be seen that the Ohio River at Cincinnati developed two distinct major crests, one on March 27, when the stage was 53.4 feet, and another on April 5 and 6, when the stage was 51.7 feet. There was also a minor crest of 36.7 feet on April 30 following a decline to 21.9 feet on April 26. In all, the Ohio River at Cincinnati was above the flood stage of 50 feet on 10 days.

There were two crests in the Mississippi River at St. Louis, one of 30.8 feet on April 5, and another of 30.3 feet on April 30, the latter resulting from the heavy rains of April 25 and 26. The river was above the flood stage of 30 feet on 10 days. At Cairo the Ohio River first reached the flood stage of 45 feet on March 22, and from that time until the end of the flood there were two crests, one of 54 feet on April 6 and 7, and another of 49.3 feet on May 4 and 5. The stage of 54 feet on April 6 and 7 was 1.8 feet higher than the previous high-water record of February 27, 1883, and only the failure of the levees in the immediate vicinity and below prevented a crest stage of at least 55 and possibly 56 feet, the latter stage representing the maximum capacity of the Cairo City Levee. Flood stages prevailed for 45 days in all.

At Memphis there were also two crests, corresponding with the conditions at Cairo. The river first reached the flood stage of 33 feet on March 24, and did not fall below it for 60 days. The great crest occurred on April 6, when the stage was 45.3 feet, 5 feet above the previous high-water mark of February 3, 1907; and here again the failure of the levees prevented a stage of at least 47 feet, or nearly 7 feet higher than the stage of 1907. The second crest of 38.9 feet occurred on May 10.

At Helena the flood stage of 42 feet was passed on March 26, and a stage below 42 feet was not again reached until May 26, making a total of 62 days that the river was above the flood stage. The highest stage occurred on April 21, and was 54.4 feet, 2.6 feet above the previous high-water record of April 4, 1897. There was but one crest after the great rise set in.

At Vicksburg the flood stage of 45 feet was reached on March 31, and the river was at or above the flood stage until May 31, a period of 62 days. There were two crests; one a principal one of 52.1 feet on April 12, and a secondary one of 48.4 feet on May 6 and 7. Heavy rains over the Yazoo watershed were responsible for the second crest. The high stage of 52.1 feet was 0.4 foot lower than the record stage of April 16, 1897, the Panther Forest and Salem crevasses being responsible for the deficiency in 1912. Had these levees remained intact, the crest stage at Vicksburg would have been 53.5 feet or 54 feet, and, if only one of the two levees had held, it is very probable that the high-water mark of 1897 would have been exceeded somewhat.

At New Orleans the river was above the flood stage of 18 feet from April 10 to June 8, inclusive, a period of 60 days. There was a single crest of 22 feet in the early morning of May 11. This was 1.6 feet above the previous high-water record of April 6 and 7, 1903, and was partially due to an unfortunate combination of high southerly winds and torrential local rains. Conditions above New Orleans had indicated a maximum stage of 21.5 feet, which was the stage actually reached after the effects of the high winds and local rains had disappeared a few hours later.

Records were also exceeded in the Atchafalaya River, the excess ranging from 2.2 to 2.8 feet. The Ouachita River failed by nearly 3 feet to equal the record of 1874.

FLOOD STAGES, 1912—COMPARATIVE DATA.

Table V shows the highest stages reached at various places during the flood, together with the dates thereof; also the highest recorded stages and dates at the same places previously to the flood of 1912, and the departures of the latter from the same. By flood stage is meant the stage above which damaging overflow ordinarily begins, and the data are repeated for the sake of convenience. On March 1, 1912, the flood stage at Memphis was increased from 33 to 35 feet, but for purposes of comparison the old flood stage of 33 feet has been used throughout this report.

TABLE V.—*Comparative data.*

Station.	River.		Highest stage.	1912 Date.	Highest stage.	Previous date.	1912.
		Feet.	*Feet.*		*Feet.*		*Feet.*
Cincinnati	Ohio	50	53.4	Mar. 27	71.1	Feb. 14, 1884	−17.7
Evansville	do	35	42.6	Mar. 31	48.0	Feb. 19, 1884	− 6.2
Nashville	Cumberland	40	46.5	Apr. 8	55.3	Jan. 22, 1882	− 8.8
Johnsonville	Tennessee	25	35.4	Apr. 6	48.0	Mar. 24, 1897	−12.6
Paducah	Ohio	43	49.9	Apr. 8–11	54.2	Feb. 23, 1884	− 4.3
Cairo	do	45	54.0	Apr. 6–7	52.2	Feb. 27, 1883	+ 1.8
Kansas City	Missouri	22	23.2	Apr. 17	38.0	June 20, 1844	−14.8
Hannibal	Mississippi	13	19.0	Apr. 8	22.5	June 8, 1903	− 3.5
St. Louis	do	30	30.8	Apr. 5	41.4	June 28, 1844	−10.6
New Madrid	do	34	44.0	Apr. 5–6	41.5	Feb. 24, 1884	+ 2.5
Memphis	do	33	45.3	Apr. 6	40.3	Feb. 3, 1907	+ 5.0
Helena	do	42	54.4	Apr. 12	51.8	Apr. 4, 1897	+ 2.6
Little Rock	Arkansas	23	24.0	May 4	32.6	May --, 1844	− 8.6
Arkansas City	Mississippi	47	55.4	Apr. 12	53.0	Mar. 27, 1903	+ 2.4
Yazoo City	Yazoo	25	30.4	Apr. 17	36.5	———, 1882	− 6.1
Vicksburg	Mississippi	45	52.1	Apr. 12	52.5	Apr. 16, 1897	− 0.4
Natchez	do	46	51.4	Apr. 14–17	50.4	Mar. 28, 1903	+ 1.0
Alexandria	Red	36	33.6	Apr. 22	41.8	July 6, 1908	− 8.2
Baton Rouge	Mississippi	35	43.8	May 11, 13	40.6	May 13–15, 1897	+ 3.2
Donaldsonville	do	28	34.8	May 11	32.8	May 13, 1897	+ 2.0
New Orleans	do	18	22.0	May 11	20.4	Apr. 6, 7, 1903	+ 1.6
Monroe	Ouachita	40	46.2	Apr. 22	49.1	— ———, 1874	− 2.9
Simmesport	Atchafalaya	41	50.1	May 11–16	47.3	May —, 1897	+ 2.8
Melville	do	37	41.9	May 6–15	39.7	June 22, 23, 1908	+ 2.2

An inspection of the above table shows that new high-water marks were established from Cairo to New Orleans, except in the vicinity of Vicksburg, where a higher stage was prevented by the crevasses at Panther Forest, Ark., and at Salem, near Lake Providence, La. Had not these crevasses occurred, or had they occurred several days later, the crest stage at Vicksburg would certainly have been at least 1 foot above the high-water mark of April 16, 1897, when the stage was 52.5 feet. The crest stage of 22 feet at New Orleans represented the maximum effect of wind and water, and was as high as it could have been under any combination of existing circumstances.

COMPARISON WITH THE FLOODS OF 1882, 1897, AND 1903.

Precipitation.—During the month of January, 1912, the precipitation was generally deficient over the Mississippi Basin except southeastern Louisiana, with the greatest deficiency, something over 2 inches, over the Cumberland and the Tennessee watersheds, and between 1 and 2 inches over the remaining areas east of Kansas City, except along the lower Ohio River, where there was a slight excess. In February there was almost a similar deficiency east of the ninety-fifth meridian, and a slight excess to the westward, while in March there was a general excess except over the Mississippi Valley above Keokuk, Iowa, and over the extreme Northwest. The excess ranged from 2 to 4 inches, and was greatest over northwestern Georgia, northern Alabama, Mississippi, southern Arkansas, and northern Louisiana, comprising princi-

pally the watersheds of the Tennessee, Yazoo, lower Mississippi, lower Arkansas, and Ouachita Rivers. For the period from January 1 to April 2, inclusive, the latter being the date of the last storm directly concerned in the flood causation, there was an excess of from 2 to 2.5 inches over the Missouri Basin east of Kansas City, and somewhat less to the northwestward; between 1 and 2 inches over the lower Ohio Basin, and generally from 2 to 2.5 inches over the remainder of the Mississippi Basin below the mouth of the Missouri River. There was, however, a deficiency, due to light January and February rains, of over 2 inches in the district extending from the extreme lower Yazoo Valley southwestward through central Louisiana, and an enormous excess over southeastern Louisiana, amounting to 5 inches at New Orleans and 19 inches at Donaldsonville, La. This excess was due to the fact that the January rains, as well as those of March, were unusually heavy.

Charts Nos. 12 to 19, inclusive (appendix), show the total and normal precipitation by months (the data for the first two days of April being incorporated with those for March), the total and normal precipitation for the entire period from January 1 to April 2, inclusive, and the departures from the normals for each month and for the entire period.

Preceding and during the flood of 1882 there was an excess of from 1 to 8 inches of precipitation above Cairo, except in the Missouri Valley, and from 8 to 12 inches below. There was a great excess (3 to 11 inches) below Cairo in January, and a comparatively small one above, while in February there was a general excess east of Kansas City, ranging from 1 to 7 inches, with the maximum over southern Illinois, southeastern Missouri, and Arkansas. During March the precipitation was nearly normal above Cairo, and from 2 to 4 inches in excess below. The flood of 1882, however, was a February flood, and the precipitation of March was not of material consequence.

Charts Nos. 20 to 26, inclusive (appendix), show the total and normal precipitation for January, February, and March, 1882, the total and normal precipitation for January and February combined, the departures from the normals for January and February, and for the two months combined.

In 1897 the precipitation was much less than in 1882. There was an excess in January over the lower Missouri and the Arkansas Basins and in the Central Valley, which brought on the normal winter rise. During February the precipitation was moderate, and really deficient, except over the upper Ohio watershed, but much of that over the Ohio Basin occurred within a short period of time, and started the flood. During March there was a general excess east of Kansas City, ranging, as a rule, from 2 to 4 inches above Cairo, and from 4 to 6 inches below. Roughly speaking, the excess in 1897 was only about one-half that of 1882, with the rapidity of fall as the balancing factor.

Charts Nos. 27 to 32, inclusive (appendix), show the normal precipitation and the actual conditions that occurred.

The precipitation that caused the flood of 1903 did not differ greatly in amount from that of 1897, although there was great difference in its distribution. In 1903 the excess above Cairo was only about one-half as large as in 1897, while below Cairo it was nearly double, the heaviest rains falling during February below Cairo, and during March above.

The charts Nos. 33 to 35, inclusive (appendix), show the actual and normal precipitation for January, February, and March, 1903.

A comparison of the precipitation charts discloses the fact that the precipitation preceding and during the flood of 1882 was much greater than that of the three other floods. That of 1897 was somewhat, although not decidedly, greater than that of 1903, and also somewhat greater than that of 1912, while that of 1903 was the least of all. So that measured by the amount of precipitation, the relative order of the four great floods was as follows: 1882, 1897, 1912, and 1903. These data, while of some interest, are not of great importance, as the rate of fall and the interval between rainstorms, as well as the character of the seasons, are the natural controlling factors.

Comparative stages.—The table immediately following shows the highest stages reached at various stations during the floods of 1882, 1897, 1903, and 1912, the highest stage at each station during the four floods being in italics. No reference is made to dates, and the table is inserted merely to display comparative data in convenient form.

Diagrams Nos. I and II (appendix), also show the same data in another form, but for a limited number of stations only.

TABLE No. VI.—*Highest river stages at various places during the floods of 1882, 1897, 1903, 1912, and 1913.*[1]

Station.	River.	Highest stage (feet).				
		1882	1897	1903	1912	1913[1]
Cincinnati, Ohio	Ohio	58.6	61.1	53.2	53.4	*70.0*
Evansville, Ind	do	44.9	43.6	42.4	42.6	*48.4*
Nashville, Tenn	Cumberland	*55.1*	48.7	40.7	46.5	44.9
Johnsonville, Tenn	Tennessee	43.8	*48.0*	33.7	35.4	33.3
Paducah, Ky	Ohio	49.9	50.9	47.6	49.9	*54.3*
Cairo, Ill	do	51.8	51.6	50.6	54.0	*54.8*
Kansas City, Mo	Missouri	....	22.8	[2] *35.0*	23.2	21.9
Hannibal, Mo	Mississippi	7.0	20.8	[2] *22.5*	19.0	14.3
St. Louis, Mo	do	28.2	31.0	[2] *38.0*	30.8	27.2
New Madrid, Mo	do	....	....	39.5	44.0	*44.5*
Memphis, Tenn	do	35.0	37.1	40.1	45.3	*46.5*
Helena, Ark	do	47.2	51.8	51.0	54.4	*55.2*
Little Rock, Ark	Arkansas	*25.7*	21.4	24.8	24.0	17.3
Arkansas City, Ark	Mississippi	....	51.9	53.0	*55.4*	55.1
Yazoo City, Miss	Yazoo	....	*31.5*	28.7	30.4	29.8
Vicksburg, Miss	Mississippi	48.8	*52.5*	51.8	52.1	52.3
Natchez, Miss	do	....	49.8	50.4	51.4	*52.4*
Alexandria, La	Red	34.8	26.3	*36.2*	33.6	24.2
Baton Rouge, La	Mississippi	....	40.6	40.0	*43.8*	41.3
Donaldsonville, La	do	....	32.8	32.2	*34.8*	32.7
New Orleans, La	do	15.8	19.5	20.4	*22.0*	20.5
Monroe, La	Ouachita	....	37.9	44.5	*46.2*	36.9
Simmesport, La	Atchafalaya	....	....	....	*50.1*	46.9
Melville, La	do	....	36.1	38.7	*41.9*	41.7

[1] Supplied in 1913. [2] Occurred later than the lower Mississippi flood.

An inspection of the above table shows clearly that there has been a steady increase in the flood heights below Cairo without a corresponding increase in the quantity of precipitation. While the highest stages occurred in 1912, the greatest precipitation occurred in 1882, and while there were no marked differences in the quantity of precipitation in 1897 and 1903, yet the stages in the latter year were considerably higher, except in certain localities where levee crevasses in 1903 were followed by some depression in the flood plane. This absence of the natural relation between volume and stage is, of course, due to some cause other than differences in the quantity of precipitation, and that cause is the influence of the levees which have gradually been extended until the entire river has been practically canalized between Cairo and the Passes. It should be stated, however, that the flood of 1912 occurred later in the season than usual, permitting the northern and western flood waters to meet and combine with those from the eastern tributaries, and thereby to increase somewhat the stages from Cairo southward.

Just what effect the upper Mississippi stages had upon the stage at Cairo can not now be stated with precision. However, the crest stage of 49.9 feet at Paducah, Ky., in 1912 indicated some disturbance of the normal gage relations between that place and Cairo, the stage of 54 feet at the latter place having been somewhat too high. In 1882 with about the same general conditions over the Ohio watershed above Cairo (Cincinnati about 5 feet higher than in 1912, but with the Cumberland and Tennessee in moderate flood only) the crest stage at Paducah was 50 feet, almost exactly the same as in 1912. In 1882 the crest stage at Cairo was 51.9 feet, with 28.2 feet at St. Louis, whereas in 1912 the crest stage at Cairo was 54 feet (and would have been at least 55 feet had the levees held), while the stage at St. Louis was 30.8 feet, or 2.6 feet higher than

in 1882. How much of this 2.1 or possibly 3.1 feet of excess at Cairo came from the excess of 2.6 feet at St. Louis, and how much was due to the extension of the levee system, the writer is unable to state.

Table VII shows in another form the progressive influence of levee construction upon the gage relations between Cairo and Helena.

TABLE VII.—*Gage relations between Cairo and New Madrid, Memphis and Helena.*

Year.	Cairo stage.	New Madrid.	Memphis.	Helena.
		Number of feet above or below Cairo stage.		
	Feet.	*Feet.*	*Feet.*	*Feet.*
1882	51.8	....	−16.8	−4.6
1897	51.6	....	−14.5	+.2
1903	50.6	−11.1	−10.5	+.4
1912	54.0	−10.0	−8.7	+.4

The effects of levee crevasses were less noticeable at Memphis than at New Madrid or Helena, and the figures show that with an open river, as in 1882, the difference between the Cairo and Memphis stages was nearly 17 feet, whereas at the present time with a closed river it is only about 9 feet, indicating a rise of 8 feet at Memphis due to the building of levees. As the levee system is now practically complete, so far as linear extent is concerned, this difference of about 8 feet will probably stand for the future, it being assumed that the losses through crevasse effect during the flood of 1912 were about the same at Cairo as at Memphis.

Comparative duration.—Table No. VIII shows the number of days the rivers at various places were at or above the flood stage and the number of days they were 5 feet or more above the flood stage during the floods of 1882, 1897, 1903, and 1912.

TABLE VIII.

Station.	River.	Flood stage.	Number of days river was at or above flood stage. 1882	1897	1903	1912	Number of days river was 5 feet or more above flood stage. 1882	1897	1903	1912
		Feet.								
Cincinnati, Ohio	Ohio	50	9	7	8	10	3	6	0	0
Evansville, Ind	....do	35	60	33	45	31	20	24	18	21
Nashville, Tenn	Cumberland	40	30	16	1	16	24	6	0	8
Johnsonville, Tenn	Tennessee	25	......	40	18	30	......	30	11	12
Paducah, Ky	Ohio	43	59	32	14	23	10	13	0	13
Cairo, Ill	....do	45	56	48	25	45	10	19	8	22
Kansas City, Mo	Missouri	22	0	6	0	8	0	0	0	0
Hannibal, Mo	Mississippi	13	0	46	0	17	0	7	0	4
St. Louis, Mo	....do	30	0	5	0	10	0	0	0	0
New Madrid, Mo	....do	34	......	54	53	57	......	19	8	25
Memphis, Tenn	....do	33	65	53	54	60	0	0	13	37
Helena, Ark	....do	42	79	61	67	62	5	35	22	50
Little Rock, Ark	Arkansas	23	6	0	2	4	0	0	0	0
Arkansas City, Ark	Mississippi	47	2	50	42	61	0	0	13	26
Yazoo City, Miss	Yazoo	25	......	71	47	75	......	34	0	23
Vicksburg, Miss	Mississippi	45	39	70	59	62	0	37	21	11
Natchez, Miss	....do	46	29	62	54	63	0	0	0	8
Alexandria, La	Red	36	......	0	7	0	......	0	0	0
Baton Rouge, La	Mississippi	35	28	64	65	69	0	18	5	48
Donaldsonville, La	....do	28	......	67	66	66	......	0	0	23
New Orleans, La	....do	18	0	52	62	60	0	0	0	0
Monroe, La	Ouachita	40	......	0	38	62	......	0	0	33
Simmesport, La	Atchafalaya	41	......	......	......	69	......	......	......	43
Melville, La	....do	37	......	0	45	81	......	0	0	0

It is rather difficult to decide from the above figures as to the relative importance of these four floods, but it appears that, measured by volume of water, the flood of 1882 was the greatest. It is true that the confinement of the waters between the levees in 1897, 1903, and 1912 resulted in a greater velocity of stream flow and consequent shortening of the flood period, but this condition was probably modified considerably by the return of the overflow and crevasse water which would operate to prolong the flood period. It is noted, however, that the extreme flood heights were more prolonged in 1912 than in 1882, 1897, or 1903, due both to levee effect and to the slow return of the overflow and crevasse water. The general superiority of the flood of 1897 over that of 1903 is also indicated, as well as the inferiority of the former to those of 1882 and 1912.

Relative importance of the four floods—Final conclusions.—If the estimates of the relative importance of the floods of 1882, 1897, 1903, and 1912, as stated in the foregoing, are accepted as correct, the general conclusions may be summarized as follows:

TABLE IX.—*Relative importance of the floods of 1882, 1897, 1903, and 1912.*

As to—	Relative order.			
	First.	Second.	Third.	Fourth.
Precipitation	1882	1897	1912	1903
Stage	1912	1903	1897	1882
Duration	1912	1882	1897	1903
As a whole	1912	1897	1903	1882

The maximum stage is of course the principal factor, the one that governs in any discussion of the problem. It is the basis of comparison for the past and of estimates for the future, and all measures that may be devised for absolute protection from future floods must be predicated upon probable gage heights, and be measured by them. To the flood of 1912, therefore, must be assigned first place in the flood history of the lower Mississippi Valley.

DAMAGE AND LOSSES.

In the statement regarding damage and losses no attention will be paid to the impairment of the levees and the amount of money necessary to restore them. The estimates given will be limited to damage to and losses of property and crops and to the losses occasioned by the enforced suspension of business. It must be remembered that it is at all times extremely difficult to arrive at any accurate conclusion as to losses from floods, and the figures given here will, of course, be estimates only. They were, however, based upon careful observation and in many instances upon actual reports from those directly interested, and they are believed to be as accurate as it was possible to make them under the conditions existing at the time. Many losses were of such a character that the money equivalent could not be estimated and many others were unreported, so that to the total losses reported it would probably be reasonable and safe to add at least 10 per cent for others regarding which data were not available.

The losses and damage will be classified into four groups as follows:

1. Property losses and damage, exclusive of crops.
2. Crop loss and damage.
3. Damage to farm lands.
4. Losses occasioned through enforced suspension of business.

In the interest of further detail the data will also be localized by reference to existing river districts as maintained by the United States Weather Bureau, it being understood that each district includes the tributary watersheds from the headquarters of the district to the headquarters of the one immedately above.

TABLE X.—*Losses and damage occasioned by the flood of 1912.*

District.	Property, exclusive of crops.	Crops.	Damage to farm lands.	Suspension of business.
St. Louis, Mo	(1)	(1)	(1)	(1)
Evansville, Ind	(1)	(1)	(1)	(1)
Nashville, Tenn	$200,000	(2)	(2)	(2)
Cairo, Ill	153,000	$412,000	$14,000	$250,000
Memphis, Tenn	[3] 9,000,000	3,000,000		
Fort Smith, Ark	35,000	75,000	15,000	
Little Rock, Ark	(4)	(4)	(4)	(4)
Vicksburg, Miss	10,208,000	14,310,000	240,000	2,100,000
New Orleans, La	5,072,500	13,870,000	125,000	12,000,000
Total	24,668,500	31,667,200	394,000	14,350,000
Plus 10 per cent for unreported losses	2,466,850	3,166,720	39,400	1,435,000
Total	27,135,350	34,833,920	433,400	15,785,000

Grand total, $78,187,670.

[1] No serious damage except delay to farming operations.
[2] Impossible to obtain estimates.
[3] Includes all except crops.
[4] No serious damage. Some replanting necessary.

The losses sustained by the railroads were about $4,000,000, or a little more than 5 per cent of the total amount.

As stated before, these figures are approximate only. They were compiled with care and it is believed that any errors would lean toward the conservative side as a whole. There were innumerable losses of many kinds that could not be reduced to the basis of dollars and cents, and if the actual truth concerning these could have been ascertained, it is probable that the totals as given above would be exceeded by several millions of dollars.

Above Cairo, where there was little overflow, the total losses were but a little over $1,000,000. In the Memphis district, where the overflowed lands comprised an area of 3,142 square miles, the losses were about $12,000,000, or nearly $4,000 per square mile, of which nearly $1,000 per square mile was in crops, actual or prospective. It was assumed that 15 per cent of the overflowed area would not be replanted, and that 30 per cent of the remainder would bear only a minimum crop because of the late planting. In the Vicksburg district the overflowed area was 5,463 square miles in extent and the losses as furnished totaled $26,858,000, or about $4,900 per square mile, of which over $2,600 per square mile was in crops, actual or prospective, it being assumed that not more than two-thirds of a full crop would be raised during the year. In the New Orleans district the overflowed area amounted to about 9,000 square miles and the losses were estimated at $31,067,700, or about $3,452 per square mile, of which about $1,541 per square mile was in crops, actual or prospective.

The total extent of the overflowed area was 17,605 square miles, or 59 per cent of the entire area subject to overflow previous to 1897. This would make the average loss per square mile about $4,440, of which nearly $1,980 per square mile was in crops, actual or prospective. In 1897 the overflowed area amounted to 13,578 square miles, about 4,000 square miles less than in 1912, and about 45 per cent of the entire area subject to overflow, or 14 per cent less than in 1912. In 1903 the water overflowed an area of only 6,820 square miles, or slightly less than 23 per cent of the entire area subject to overflow. No estimates were made of the losses occasioned by these two latter floods, but they were doubtless less per square mile than in 1912, as both occurred earlier in the season, thereby largely reducing the item of prospective crop loss. Values were also considerably lower in 1897 and 1903 than in 1912.

THE WORK OF THE WEATHER BUREAU IN THE FORECASTING OF FLOODS.

The most important function of the Weather Bureau in connection with the conduct of its river and flood service is the preparation and issue of river forecasts and flood warnings. It is not a matter of general knowledge that forecasts of coming stages are issued daily along all the navigable rivers, and that to the uniform correctness of these forecasts is due a large share

of whatever of success and prosperity has attended river navigation. Flood forecasts are issued for all except the smallest rivers, and with this feature of the work the public is more familiar.

Precision in the work of river and flood forecasting was first attempted in 1892, and since that time the work has been prosecuted with such constantly increasing success and accuracy that at the present time the variations of the actual from the forecast stages in all except the precipitous mountainous streams are practically negligible, and this notwithstanding the fact that the work from Cairo southward has been greatly complicated at times by reason of levee crevasses. Let us quote briefly from Bulletin E, Weather Bureau, Floods of the Mississippi River, Section IV, paragraph 83:

The essential duty of the Weather Bureau in this work is the issuance of warnings of impending floods. For this purpose the official at each river center is assigned a certain territory, for the proper warning of which he is held responsible. From the press reports and other sources of information it appears that this duty was well performed in the late flood (1897). The conditions having become critical, a special warning was issued from the Washington office on March 15 that "the impending flood will prove very destructive in Arkansas and northern Louisiana." Again, on March 19, a special warning was issued that "the floods in the lower Mississippi during the next ten days or two weeks will, in many places, equal or exceed in magnitude and destructiveness those of any previous years, and additional warning is given to the residents of the threatened districts in Arkansas, Louisiana, and western Mississippi to remove from the region of danger." Indeed, so completely was the public warned, that it caused criticism in certain quarters that the bureau was needlessly alarming the people in the threatened districts. Subsequent events, however, fully justified the action of the Weather Bureau.

Similar criticism was made during the flood of 1903 and again during the present year, but in less pronounced form, as previous said experiences had taught the people that the warnings of the Weather Bureau must be taken at their full significance if loss of life and property are to be avoided. It is estimated that during the flood of 1897 property to the value of $15,000,000 was moved to places of safety as a result of the Weather Bureau warnings, and an equal amount, at least, during the flood of 1903. During the flood of 1912, according to such estimates as were obtainable, property to the value of $16,180,000 was saved, of which about $10,000,000 was in the district below Vicksburg, Miss. The total annual cost of the river and flood service for the entire country, including telegraph and telephone tolls is about $80,000, or only about one-half of 1 per cent of the value of the property saved in this one flood.

Specific warnings were issued each day during the flood, and they covered periods of time ranging from three or four days to more than four weeks in advance. The warnings for New Orleans were issued nearly five weeks in advance, and were not changed in the interim except as to the date of occurrence of the crest stage, the numerous crevasses at times interfering with the rate of streamflow.

General warnings and statements were also issued from time to time at the central office at Washington. A specimen bulletin follows:

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., April 3, 1912.

SPECIAL FLOOD BULLETIN.

The river situation is critical from Cairo to the mouth of the Mississippi. If the levees hold, the floods will doubtless be the greatest of which the Government has record.

Considering the water now in sight, and without any further heavy rain, the Mississippi River below Vicksburg will rise until the early part of May, and if the levees hold the river will reach about 52 feet at Natchez, 42 feet at Baton Rouge, 33.5 feet at Donaldsonville, and 21.5 feet at New Orleans. These figures are from 1 to 1.5 feet higher than any previous record.

The warning issued Tuesday for at least 44 feet at Memphis by Saturday or Sunday, if the levees hold, is repeated and preparations should be made accordingly. The highest water at Memphis previous to the present flood was 40.3 feet on February 3, 1907.

At Vicksburg the 50-foot stage will be passed by Saturday or Sunday, and if the levees hold a stage of between 53.5 and 54 feet is likely to occur later. The highest known water at Vicksburg is 52.5 feet, which occurred on April 16, 1897.

Helena, Ark., will pass the 50-foot stage some time to-day and continue to rise, but the greatest stage can not be forecast at this time, owing to the uncertainty as to the overflow water above.

At Cairo the stage of 56 feet, which was forecast yesterday to occur within three or four days, will not be reached because of the breaking of the levees below the city, and it is probable that the greatest stage will be reached within two days, but not much over 54 feet.

Warnings of the beginning of these floods were issued by the Weather Bureau as early as March 16, and in each case have preceded the arrival of flood stages.

WILLIS L. MOORE,
Chief U. S. Weather Bureau.

These bulletins, as well as all forecasts and warnings, were given the widest and most liberal distribution through the medium of the telegraph, the telephone, the mails, railroads, boats, special messengers, and every other available means, so that all the inhabitants of the flooded districts were given ample advance notice as well as the fullest information during the progress of the flood.

A great many testimonials, press and otherwise, were received. These paid tribute to the work of the Weather Bureau in connection with the flood.

Chart 1, Part 1.

Drainage Basin of the Mississippi River.

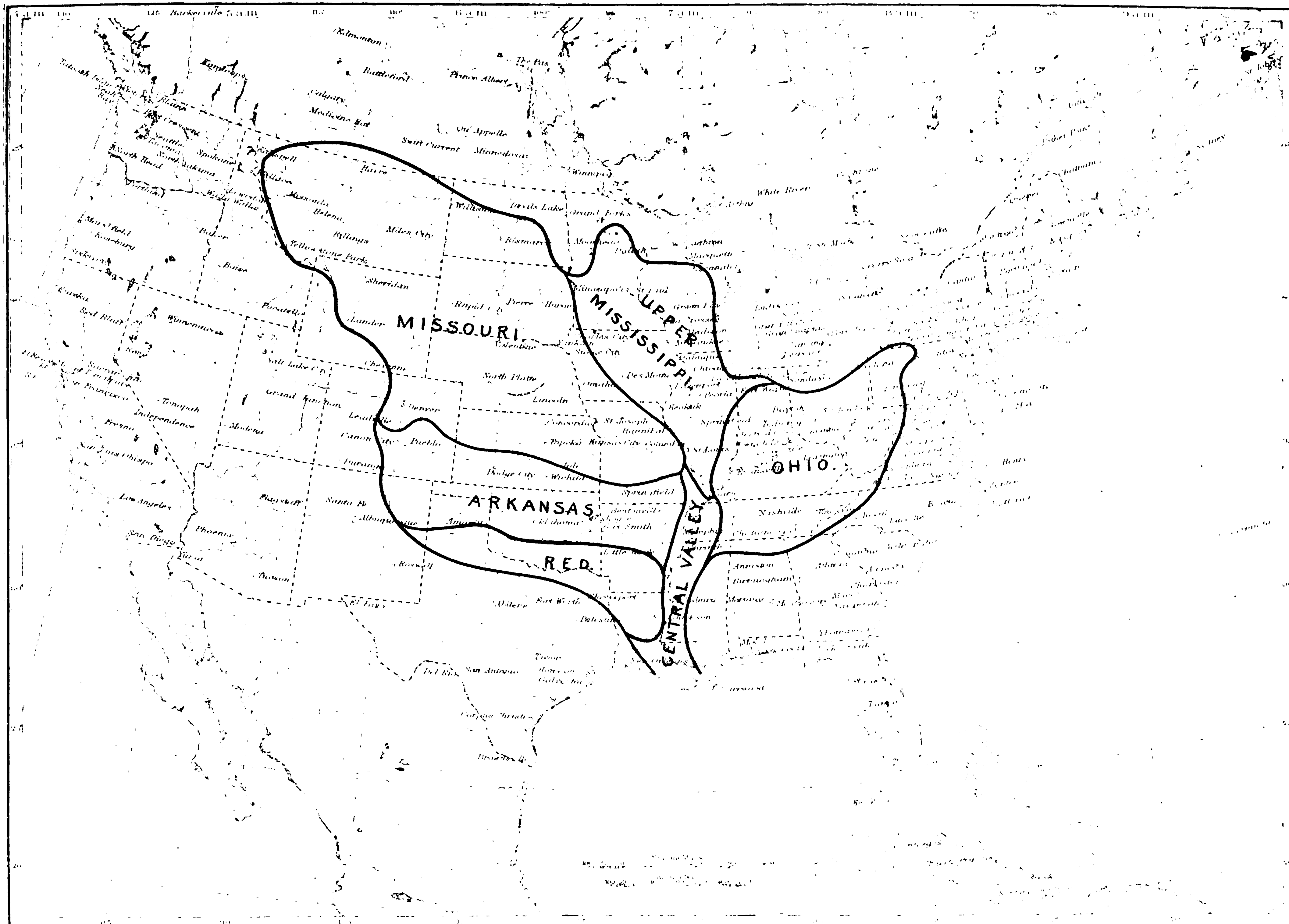


Chart 2, Part 1. Weather Map, 8 a. m., March 11, 1912, and precipitation during following 24 hours.

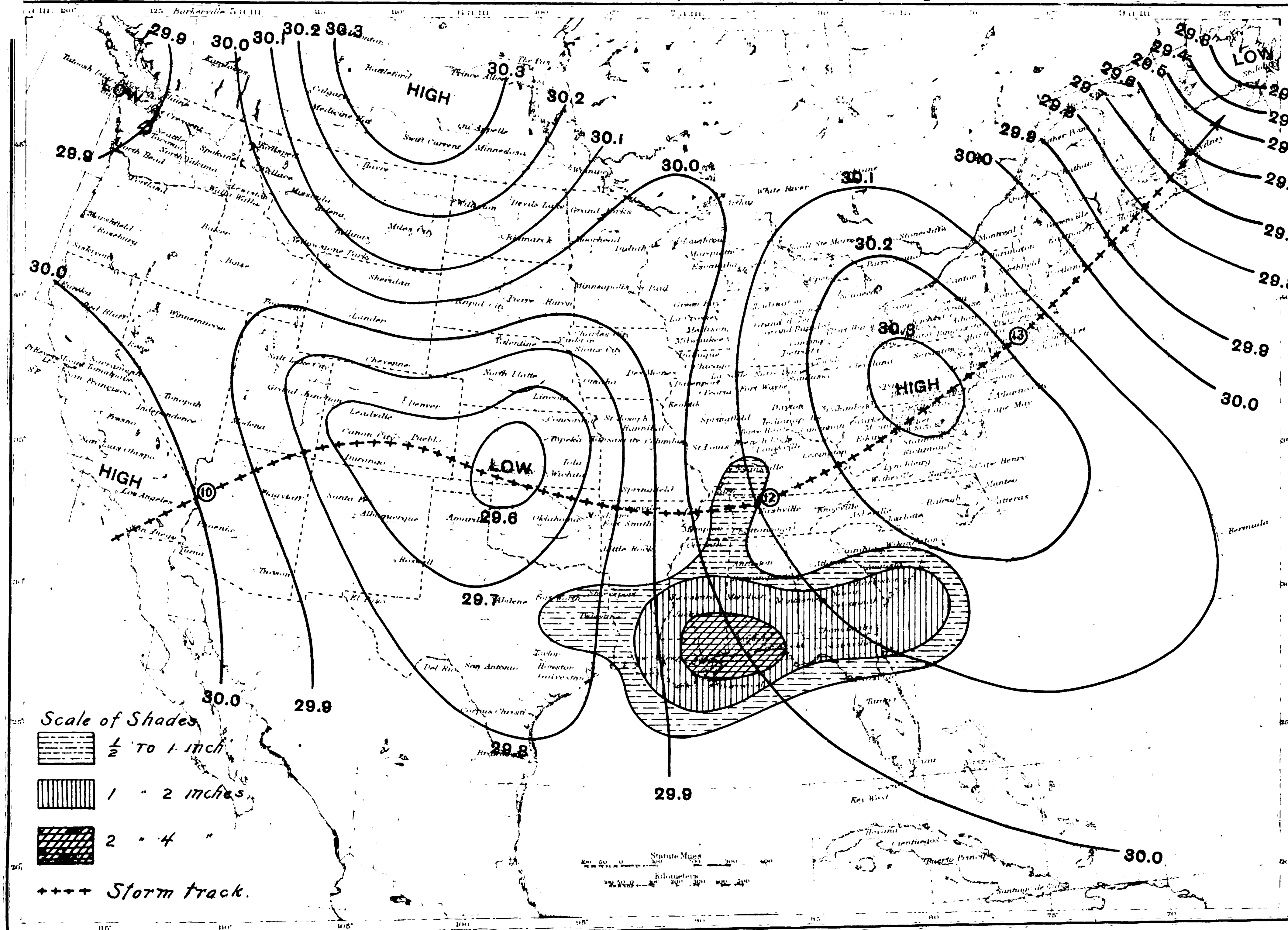


Chart 3, Part 1.

Weather Map, 8 a. m., March 14, 1912, and precipitation during following 24 hours.

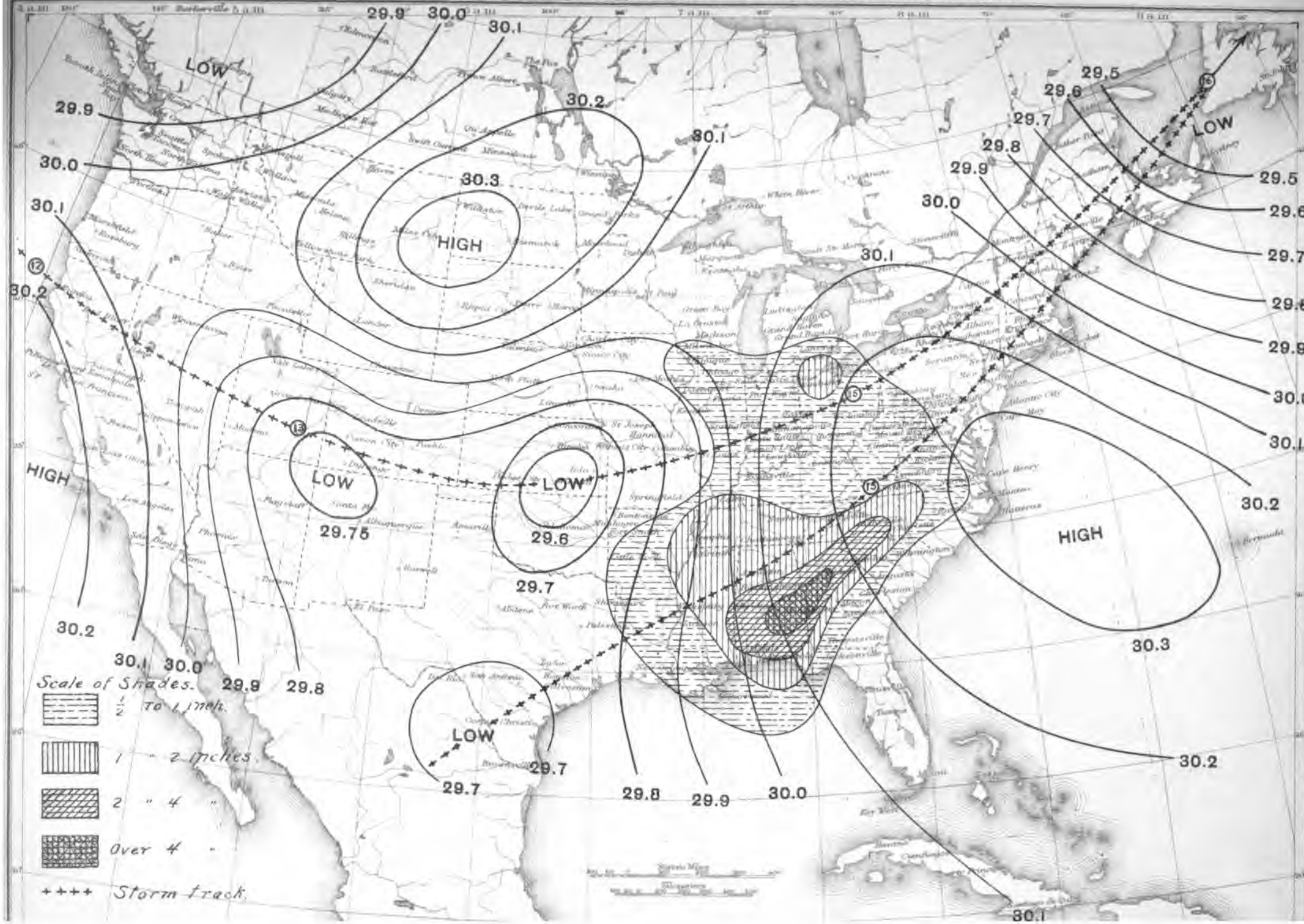


Chart 4, Part 1. Weather Map, 8 a. m., March 20, 1912, and precipitation during following 24 hours.

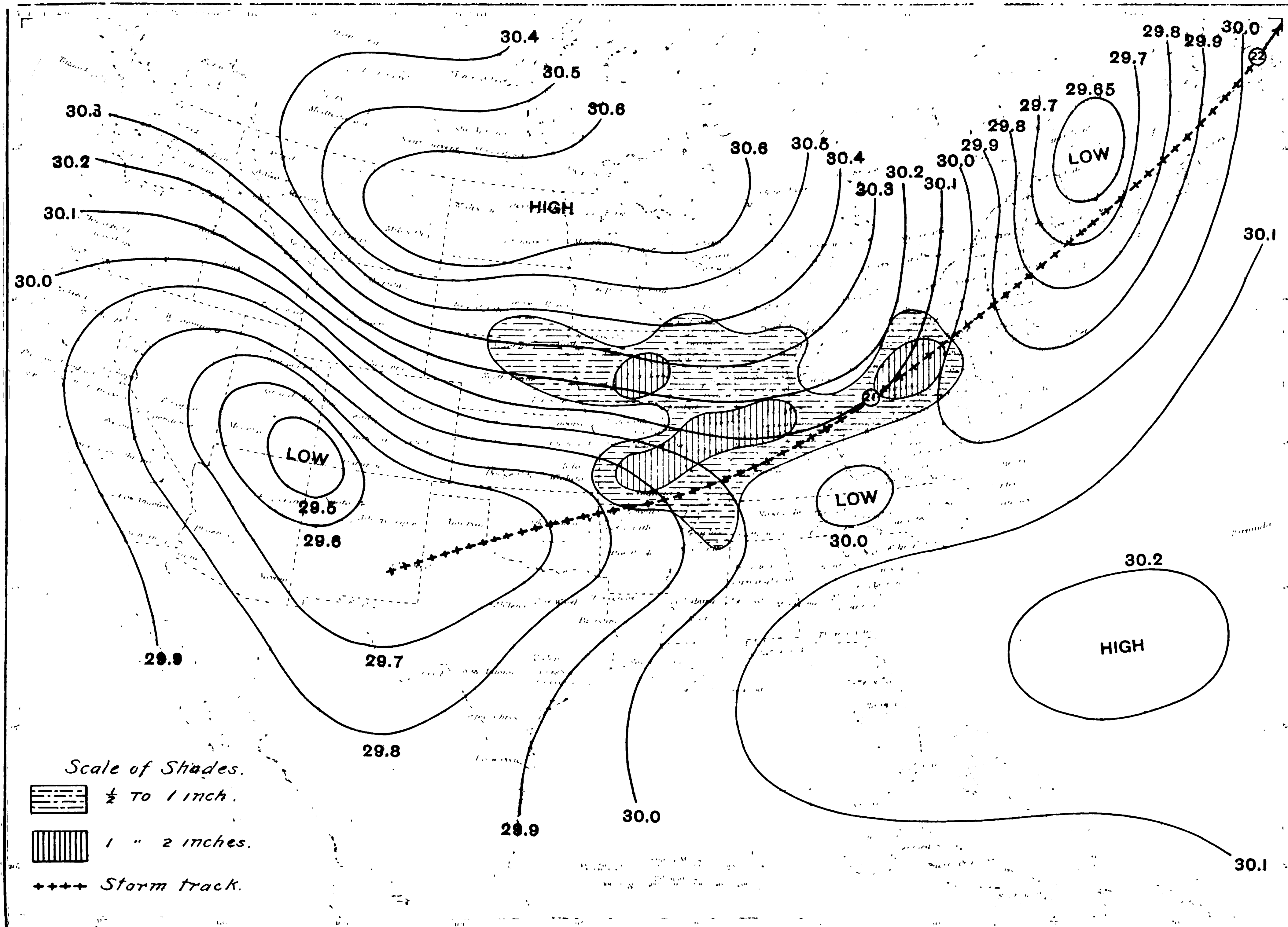


Chart 5, Part 1. Weather Map, 8 a. m., March 23, 1912, and precipitation during following 24 hours.

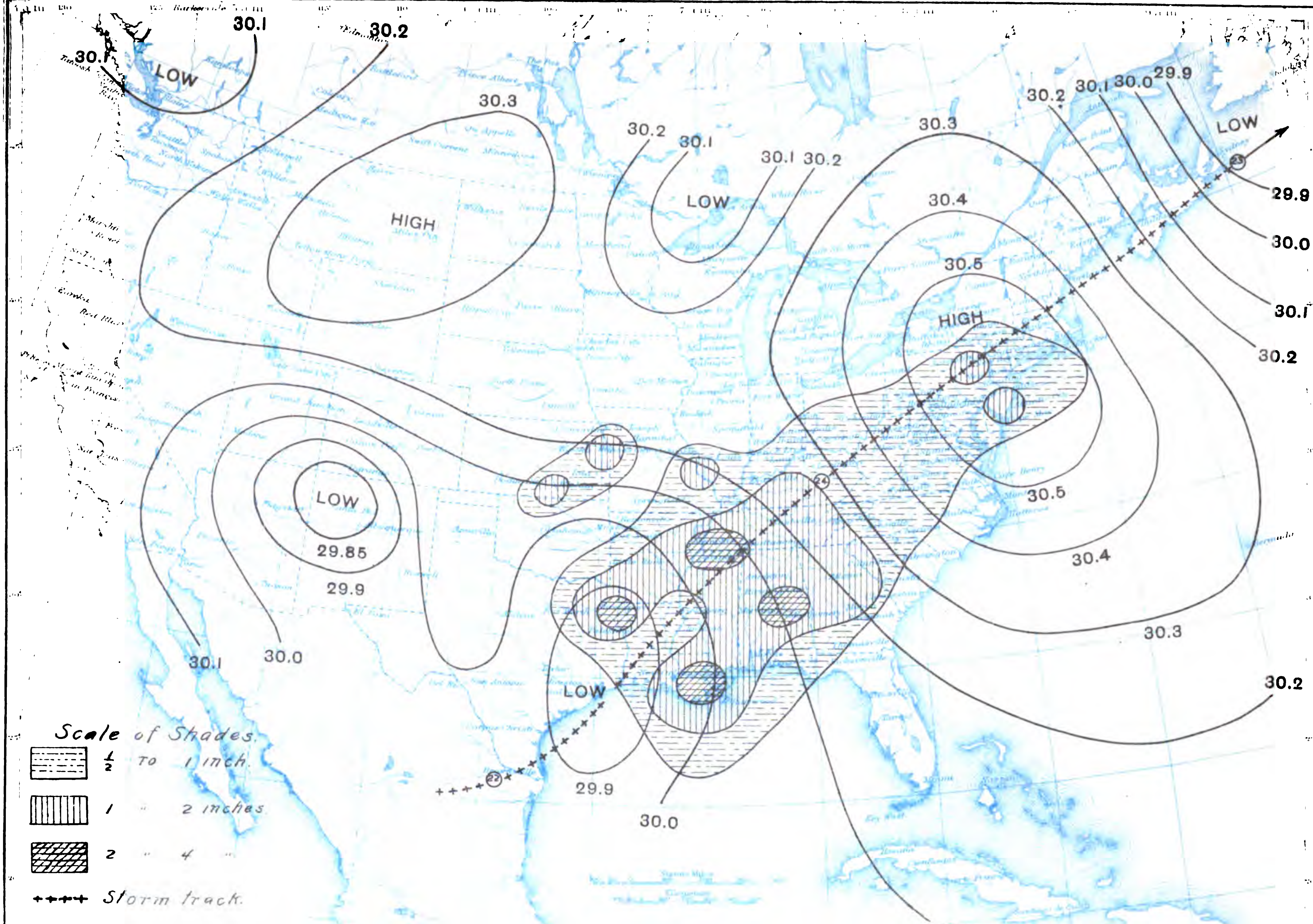


Chart 6, Part 1. Weather Map, 8 a. m., March 28, 1912, and precipitation during following 24 hours.

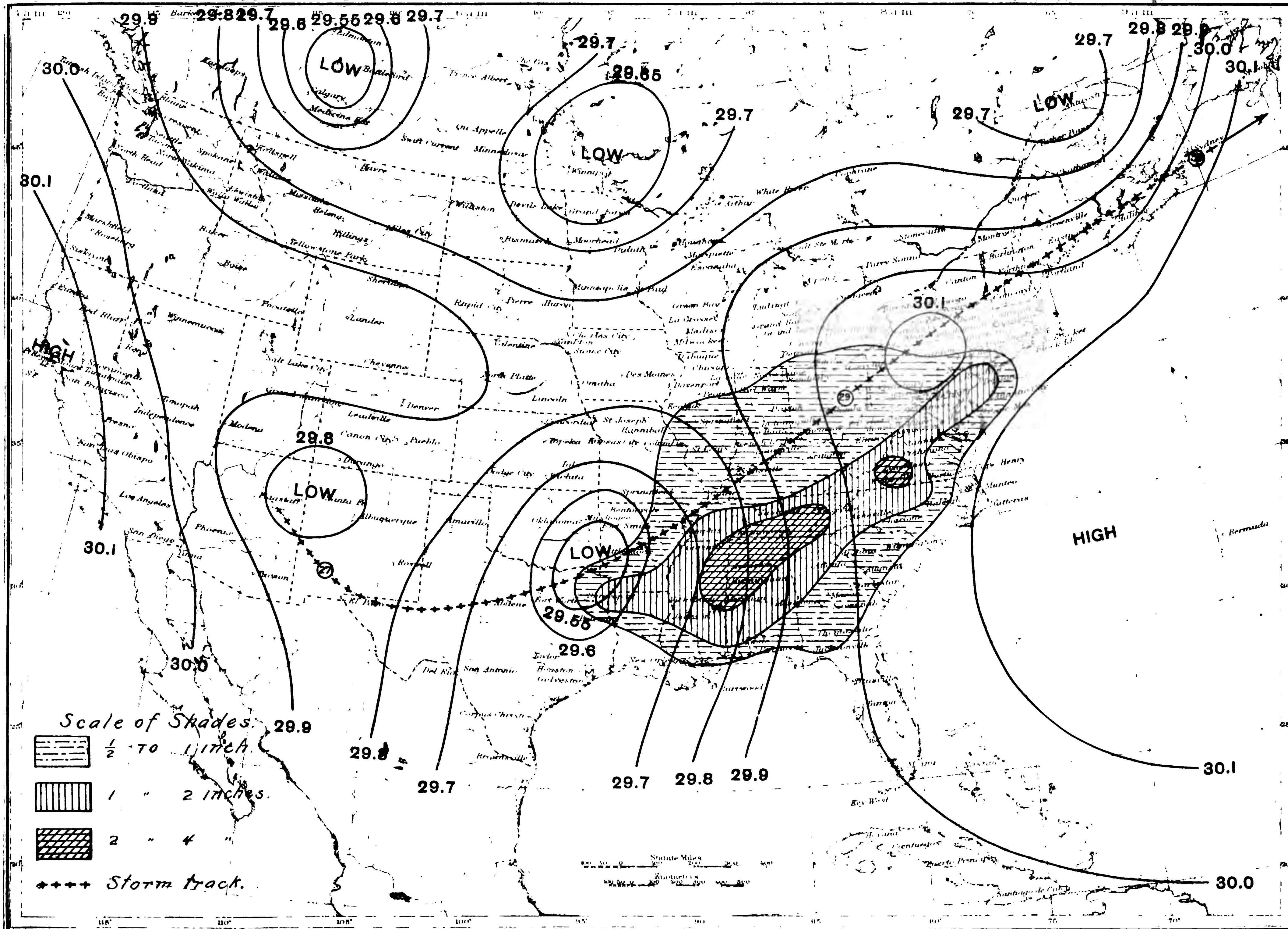
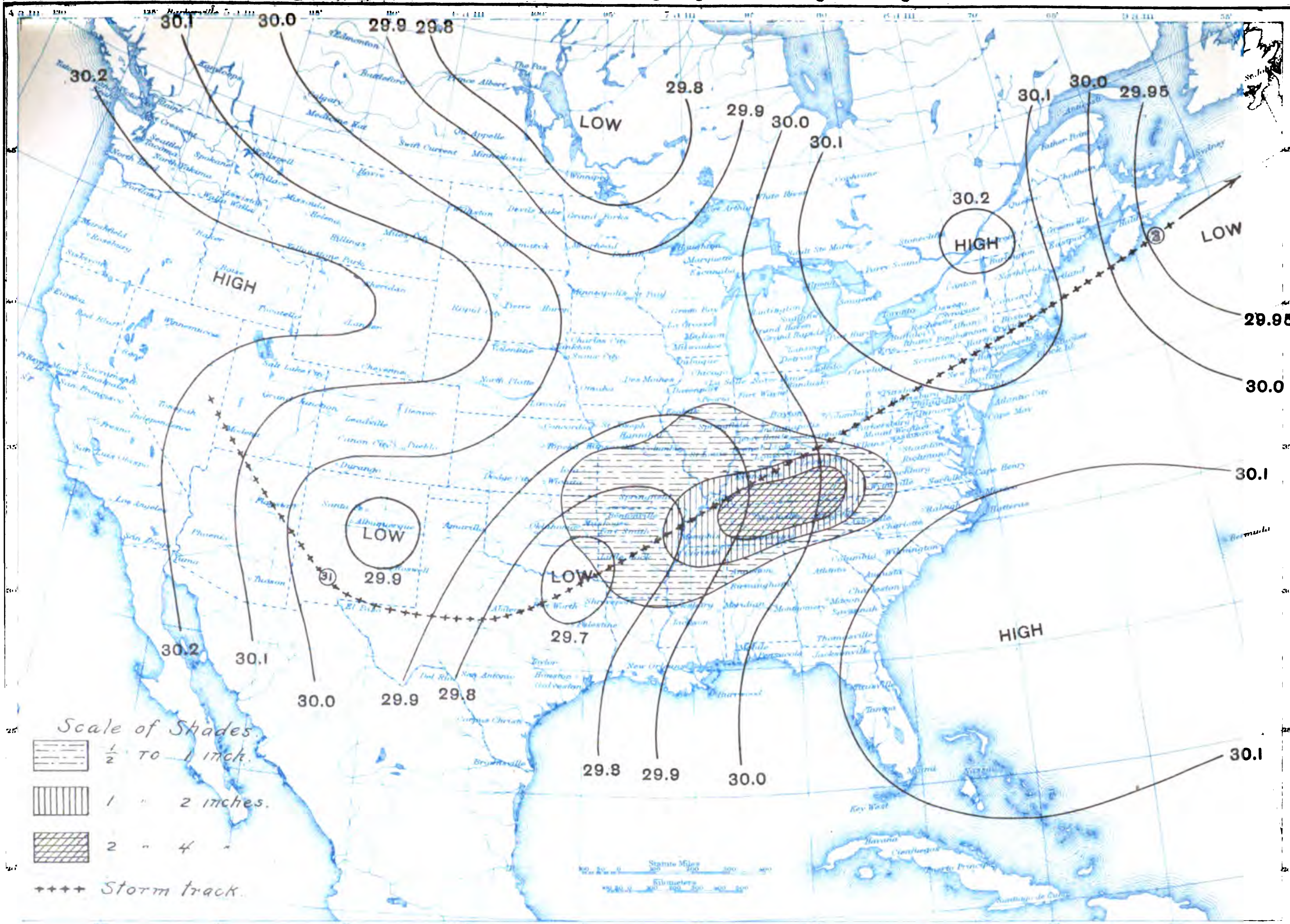
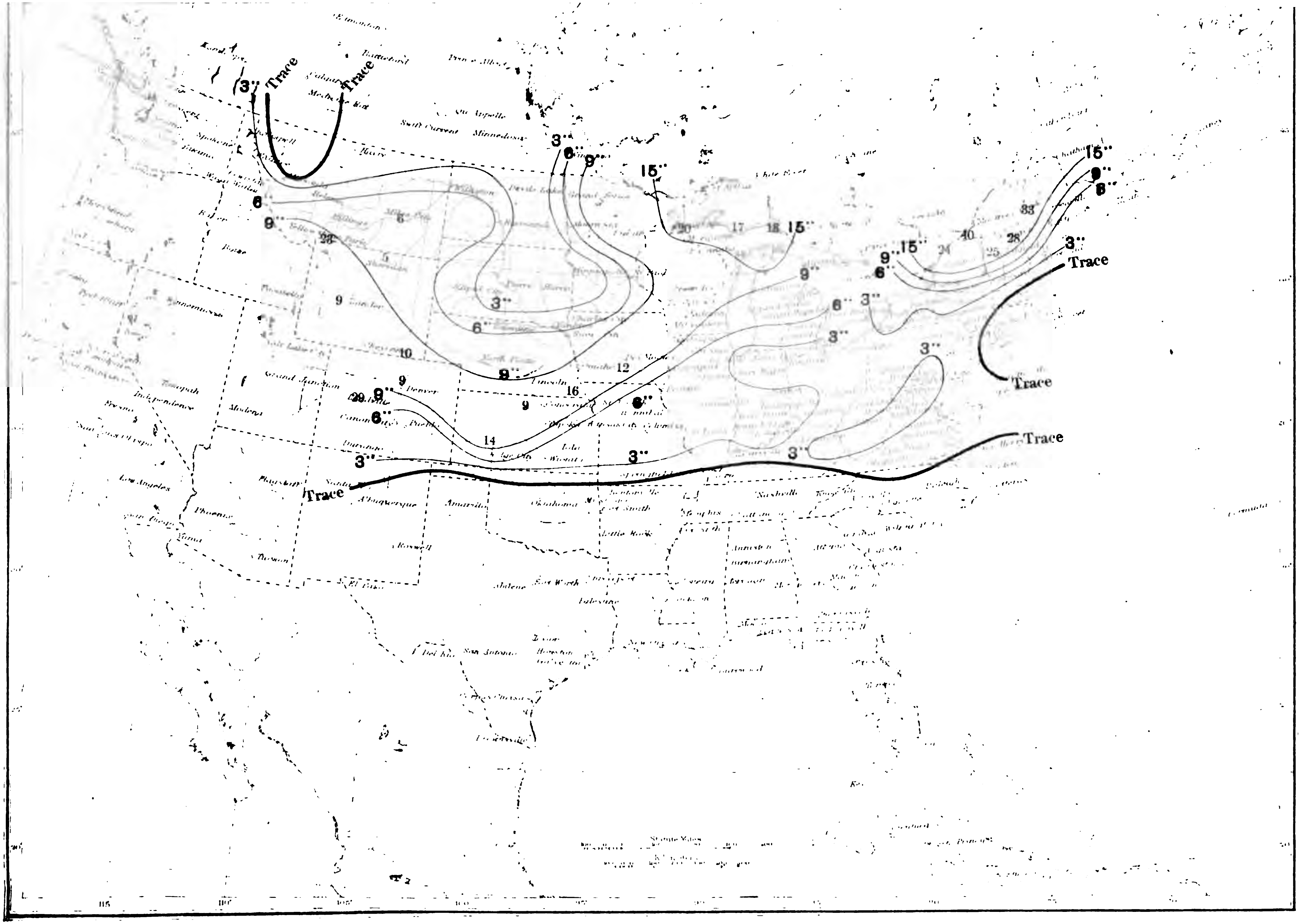


Chart 7, Part 1.

Weather Map, 8 a. m., April 1, 1912, and precipitation during following 24 hours.





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Pueblo
Durango
Lincoln
Los Angeles
Phoenix
Tucson
Amarillo
Oklahoma
Little Rock
Nashville
Roswell
El Paso
Abilene
Fort Worth
Palestine
San Antonio
Houston

Chart 9, Part 1.

Depth of snow on ground March 11, 1912 (inches).

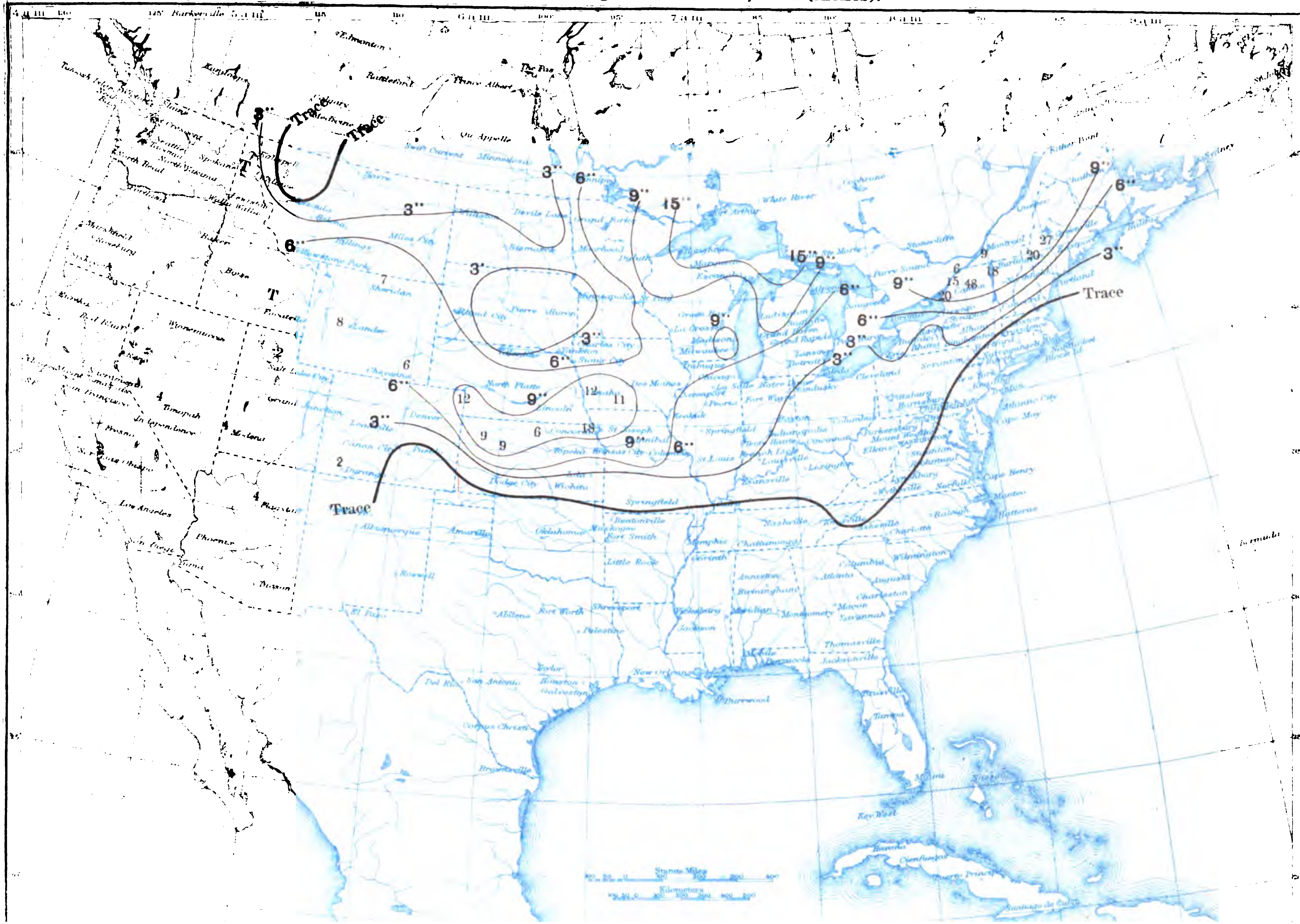


Chart 10, Part 1.

Depth of snow on ground March 18, 1912 (inches).

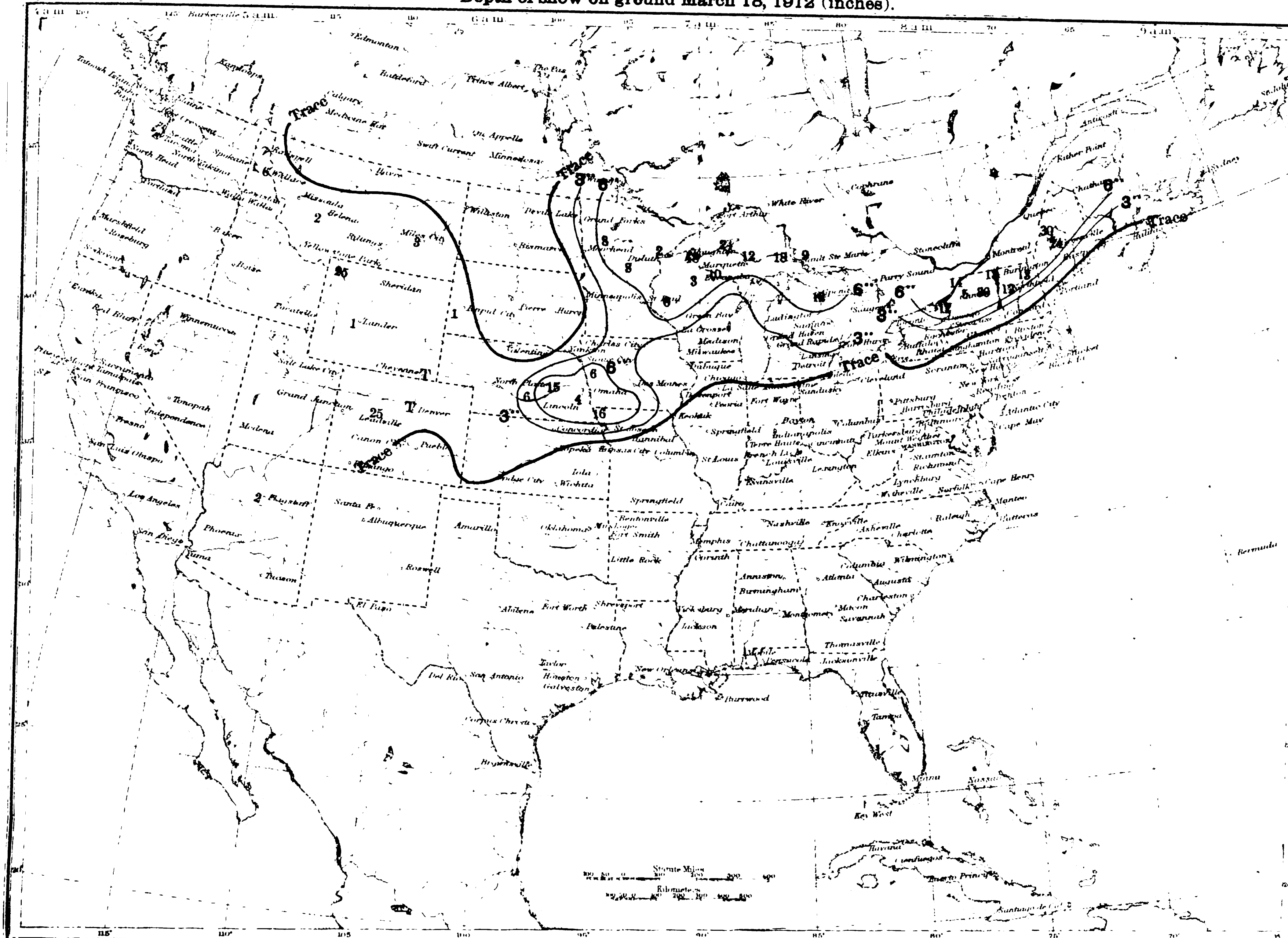


Chart 11, Part 1. Depth of snow on ground March 25, 1912 (inches).

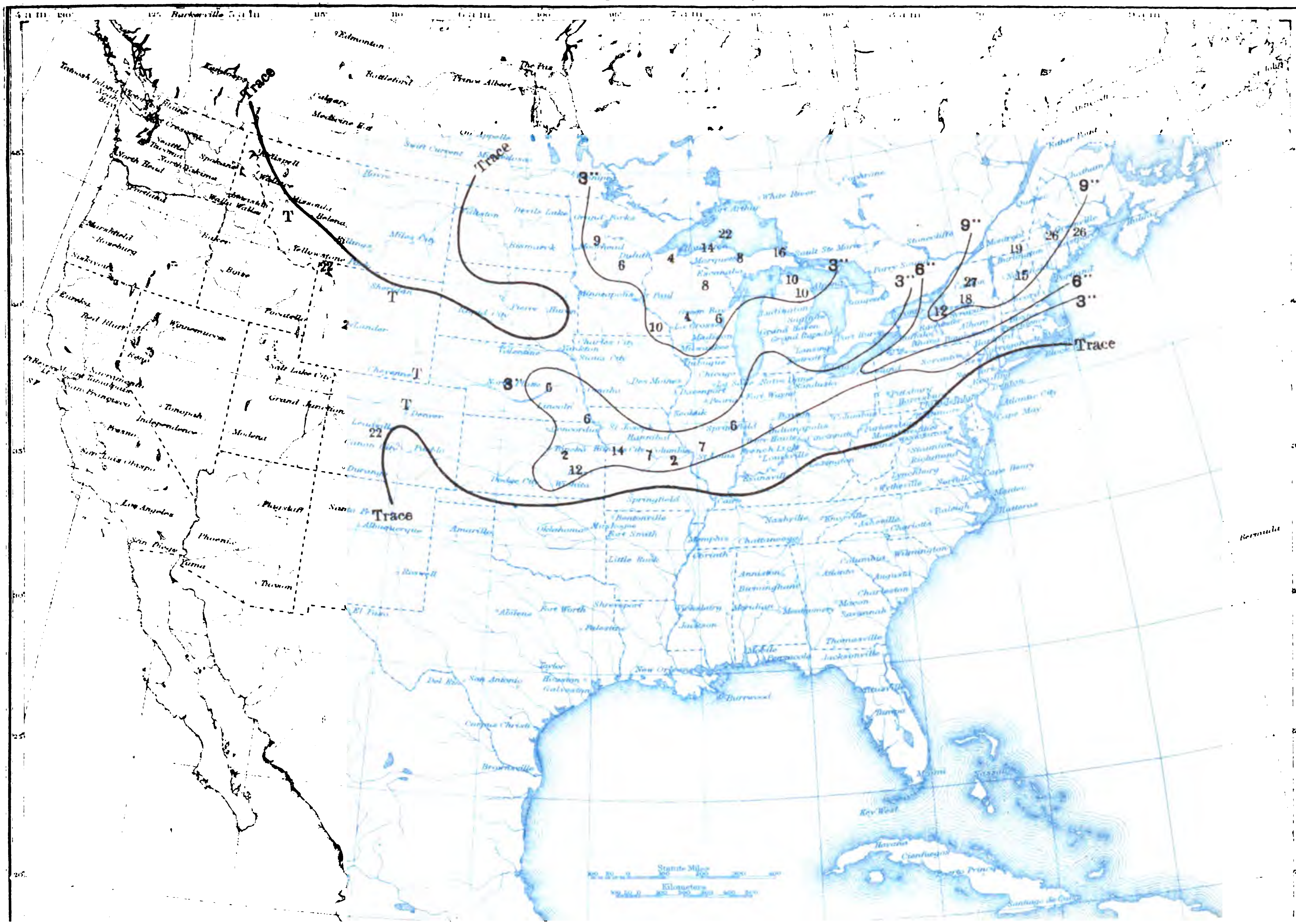


Chart 12, Part 1.

Normal and actual precipitation, January, 1912 (inches).

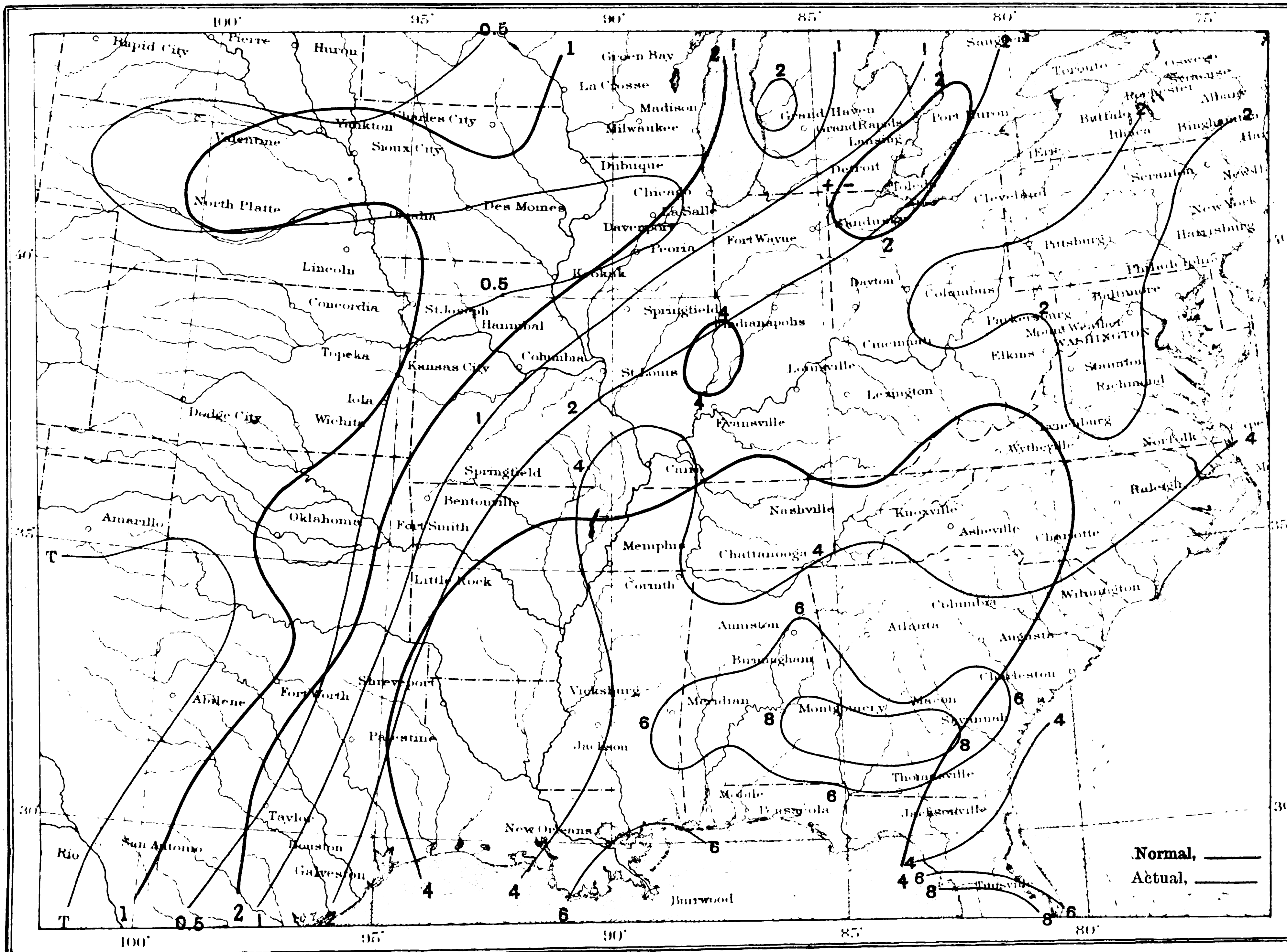


Chart 13, Part 1.

Normal and actual precipitation, February, 1912 (inches).

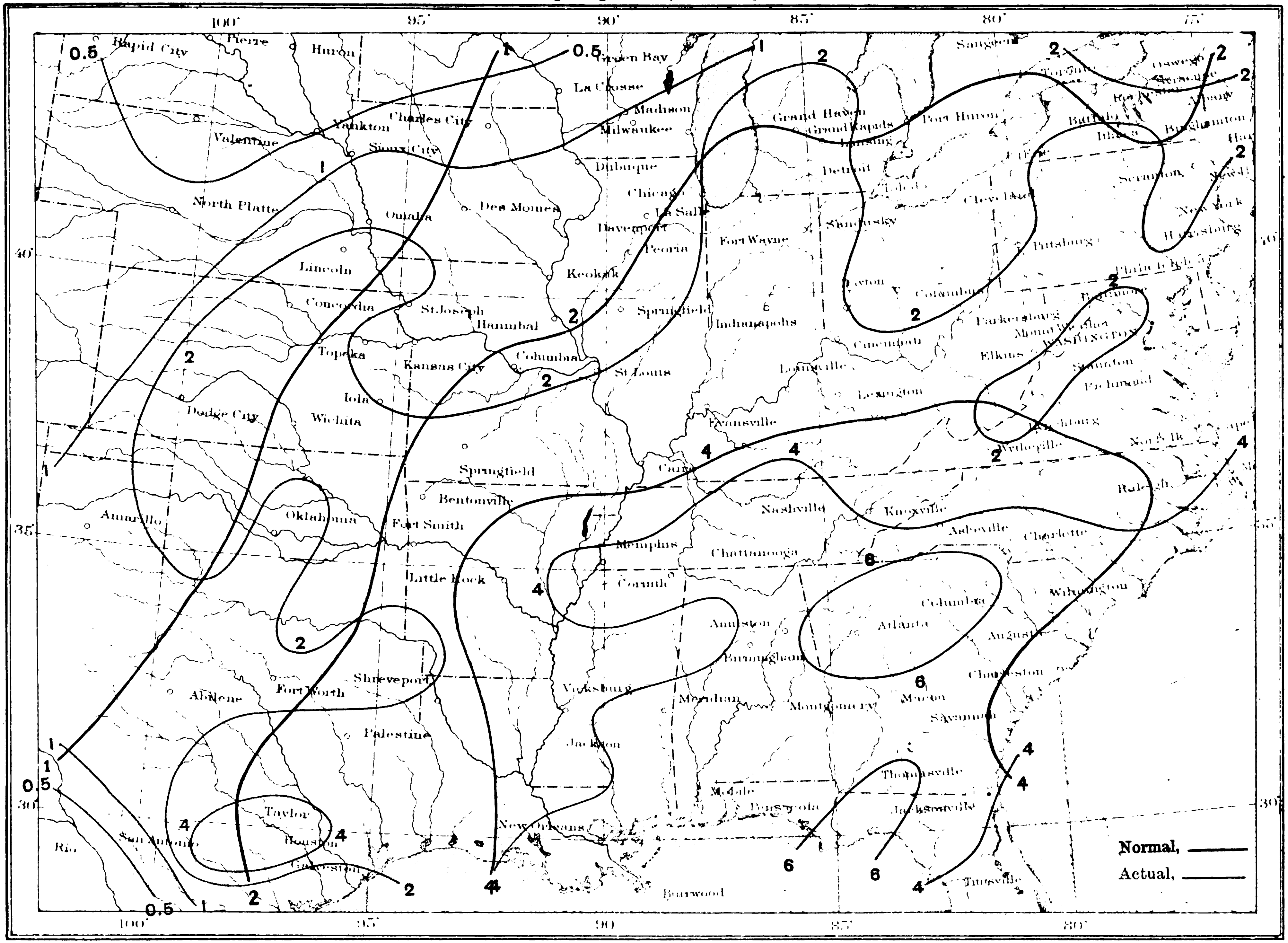


Chart 14, Part 1. Normal and actual precipitation, March, 1912 (inches).

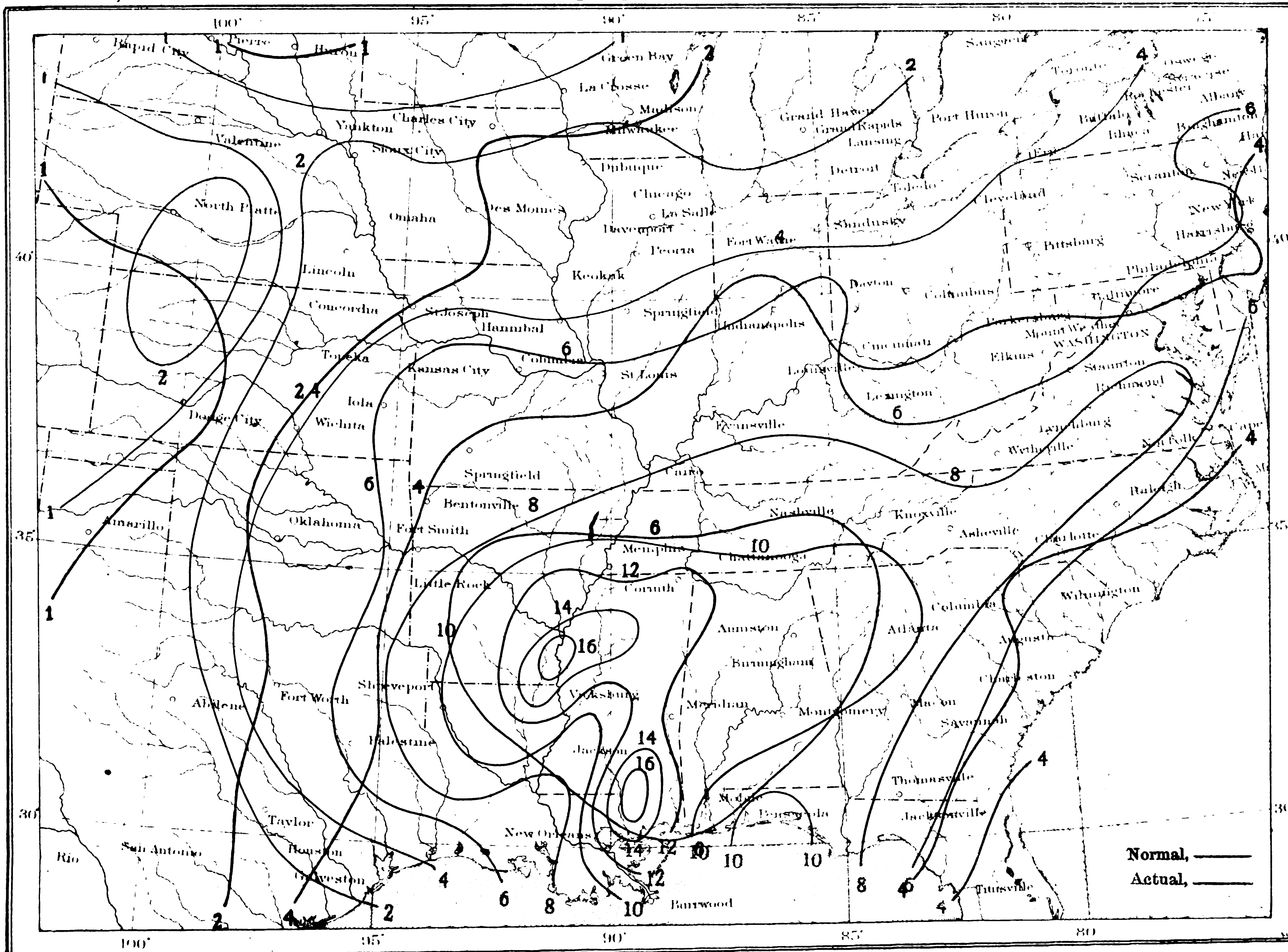


Chart 15, Part 1. **Normal and actual precipitation, January 1 to April 2, 1912 (inches).**

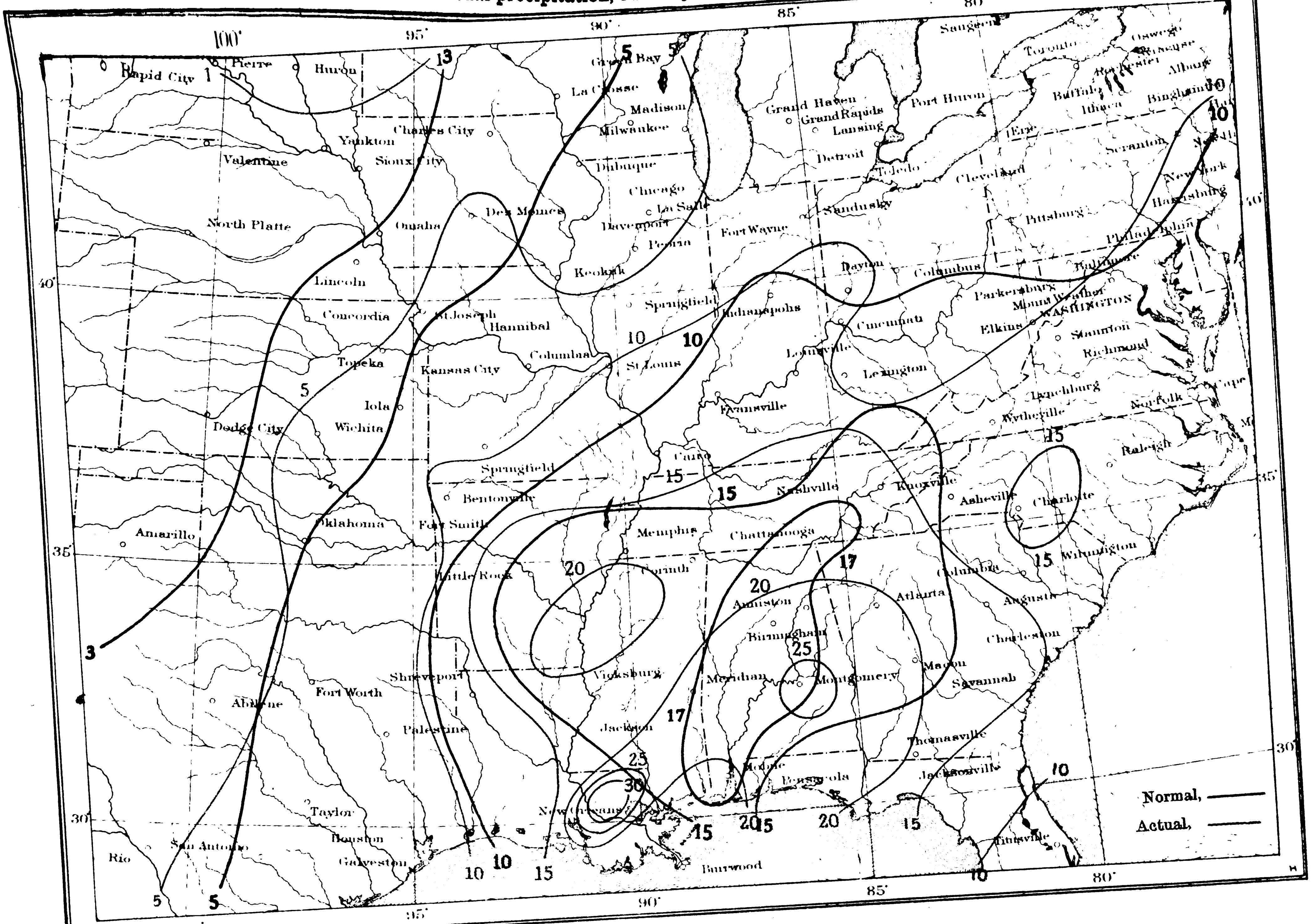


Chart 16, Part 1. Departure from normal precipitation, January, 1912 (inches).

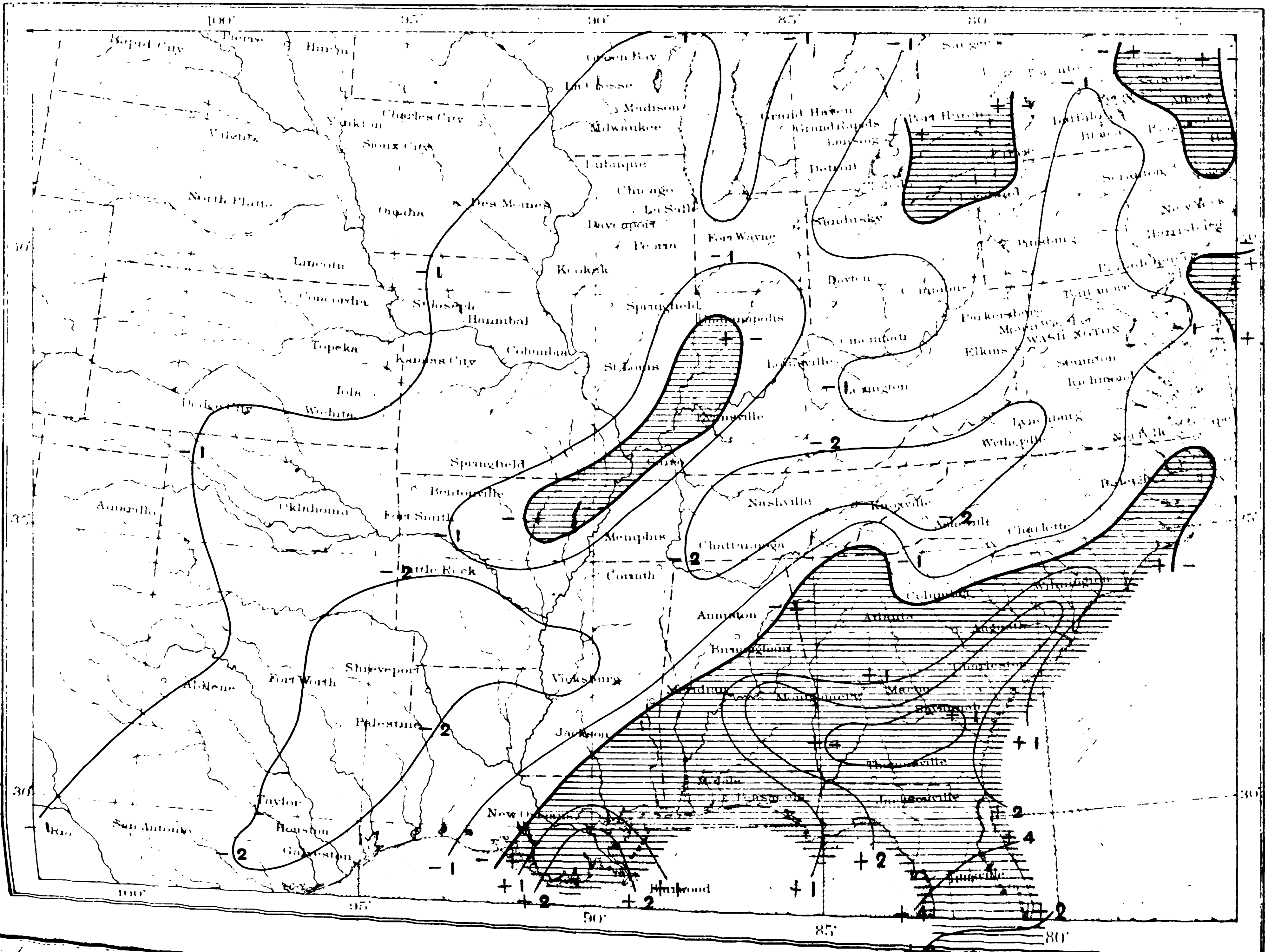


Chart 17, Part 1. **Departure from normal precipitation, February, 1912 (inches).**

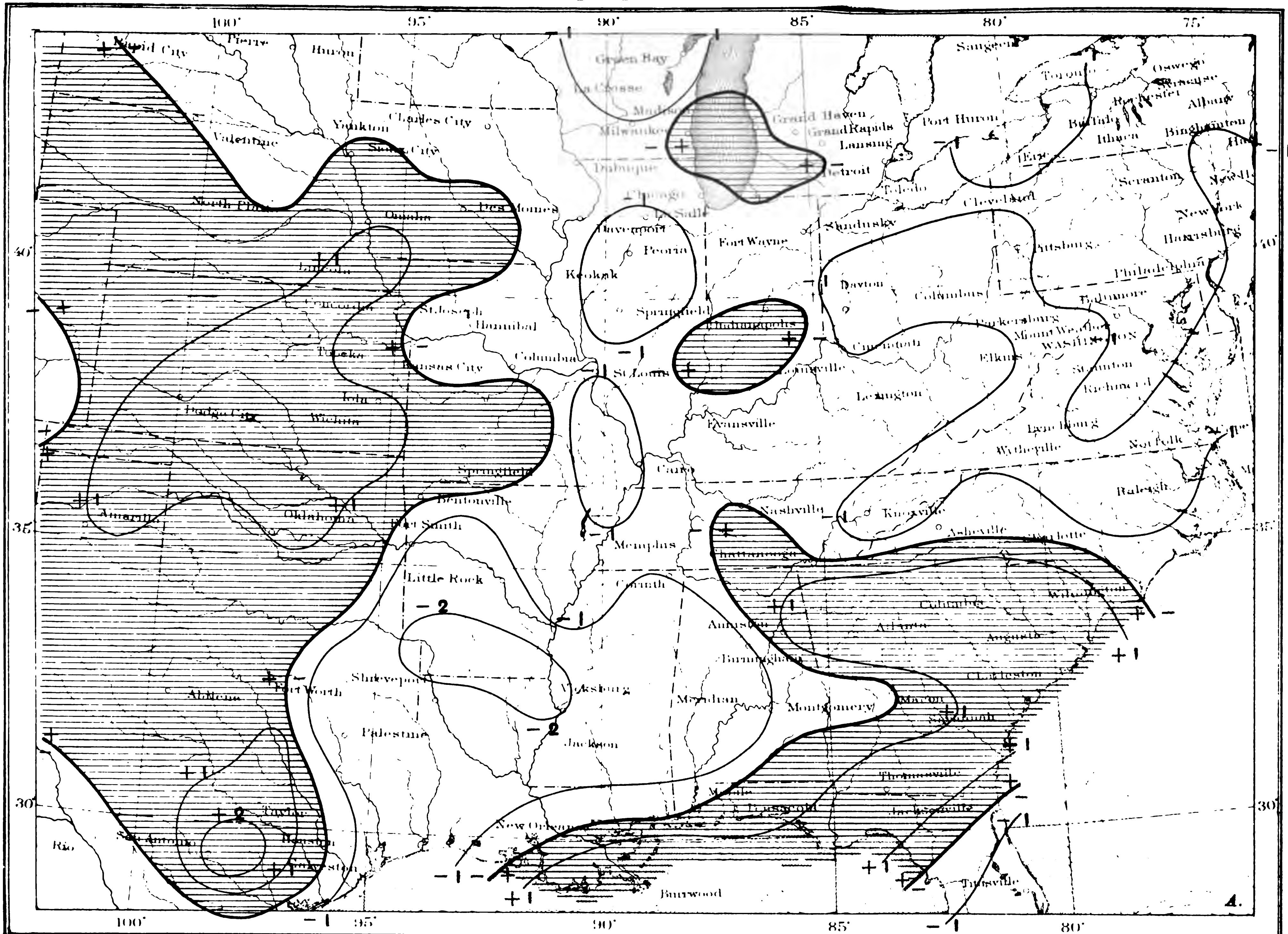


Chart 18, Part 1. Departure from normal precipitation, March 1 to April 2, inclusive, 1912 (inches).

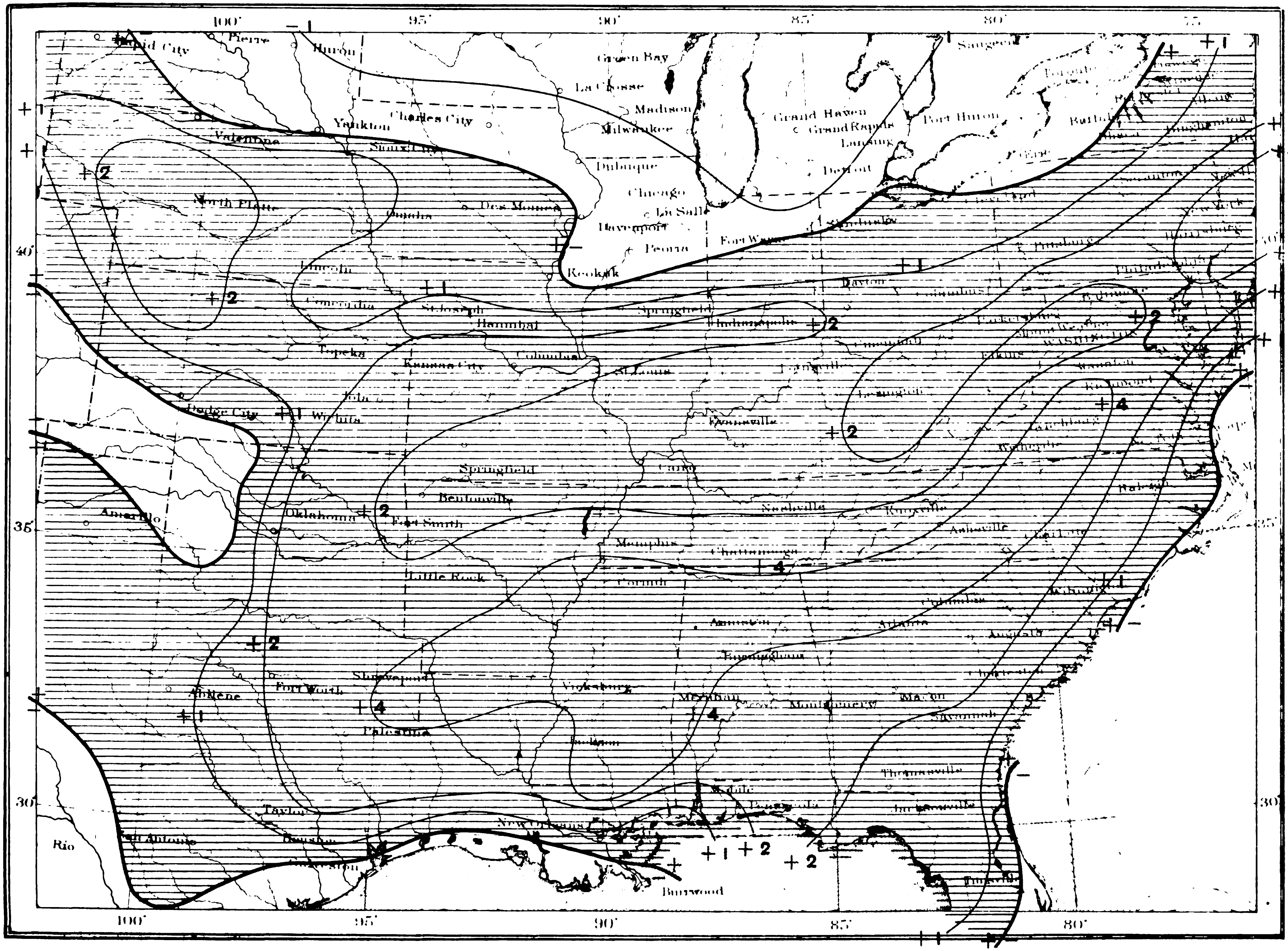


Chart 19, Part 1. **Departure from normal precipitation, January 1 to April 2, inclusive, 1912 (inches).**

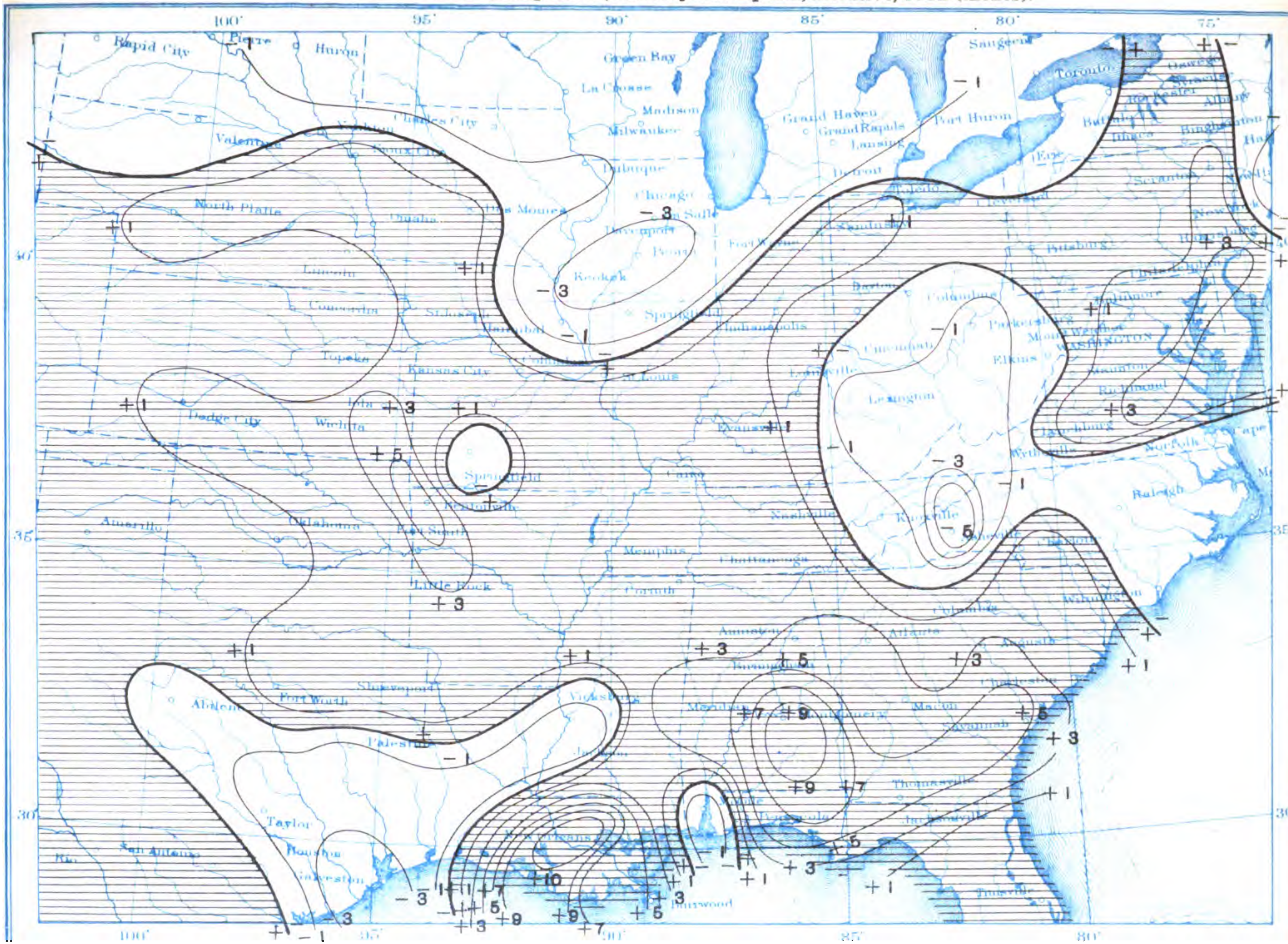


Chart 20, Part 1.

Normal and actual precipitation, January, 1882 (inches).

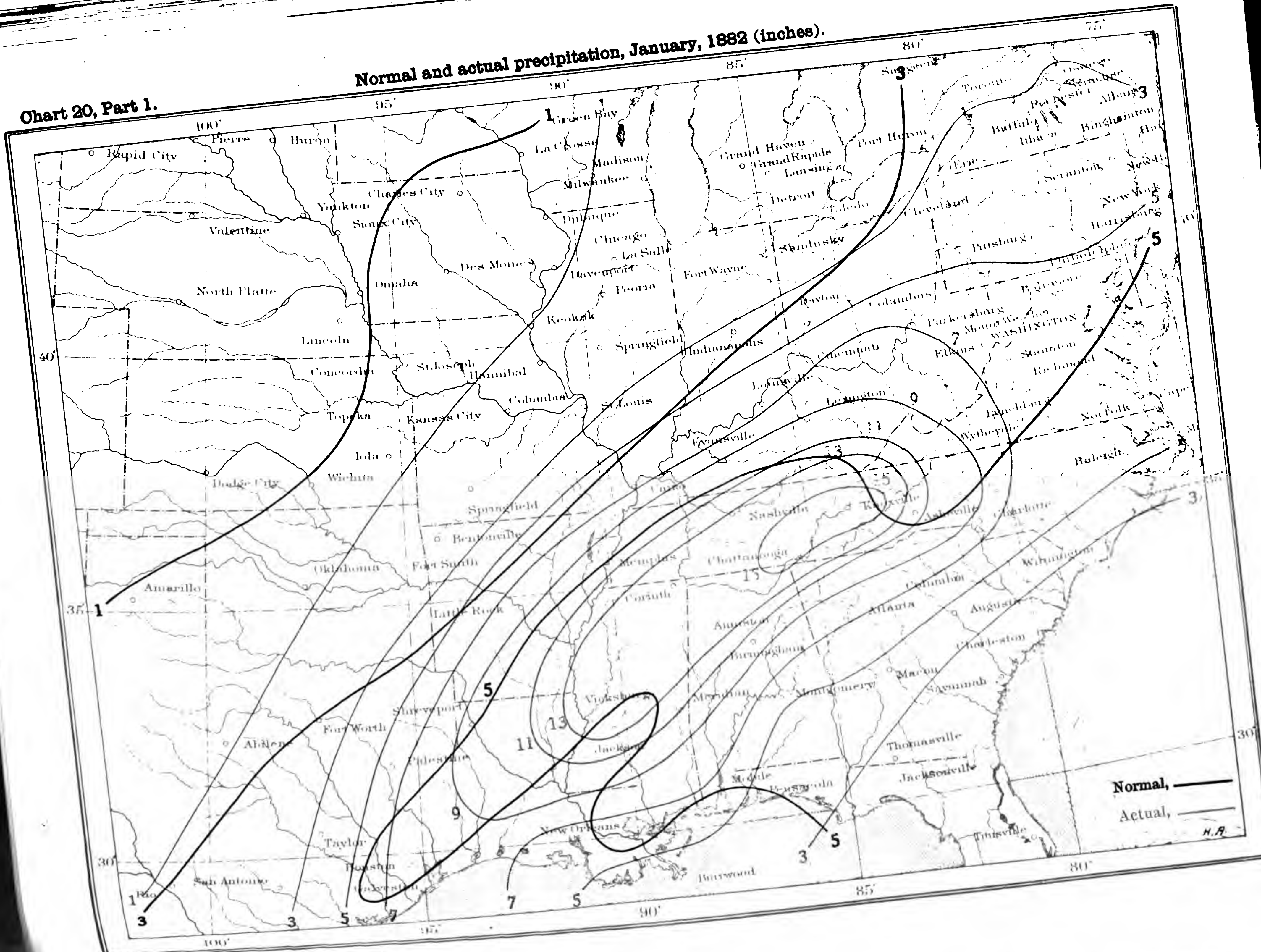
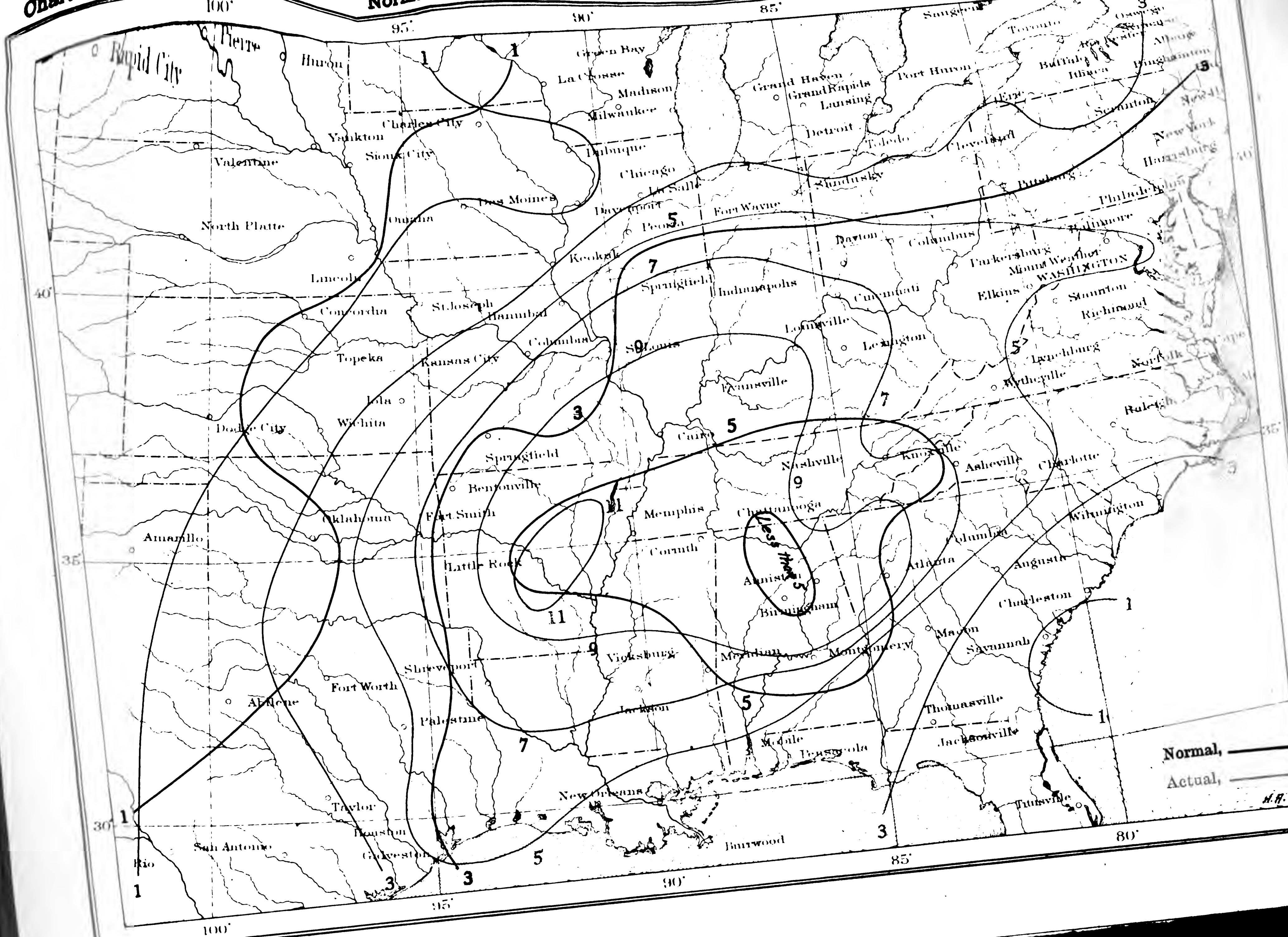


Chart 21, Part 1.

Normal and actual precipitation, February, 1882 (inches).



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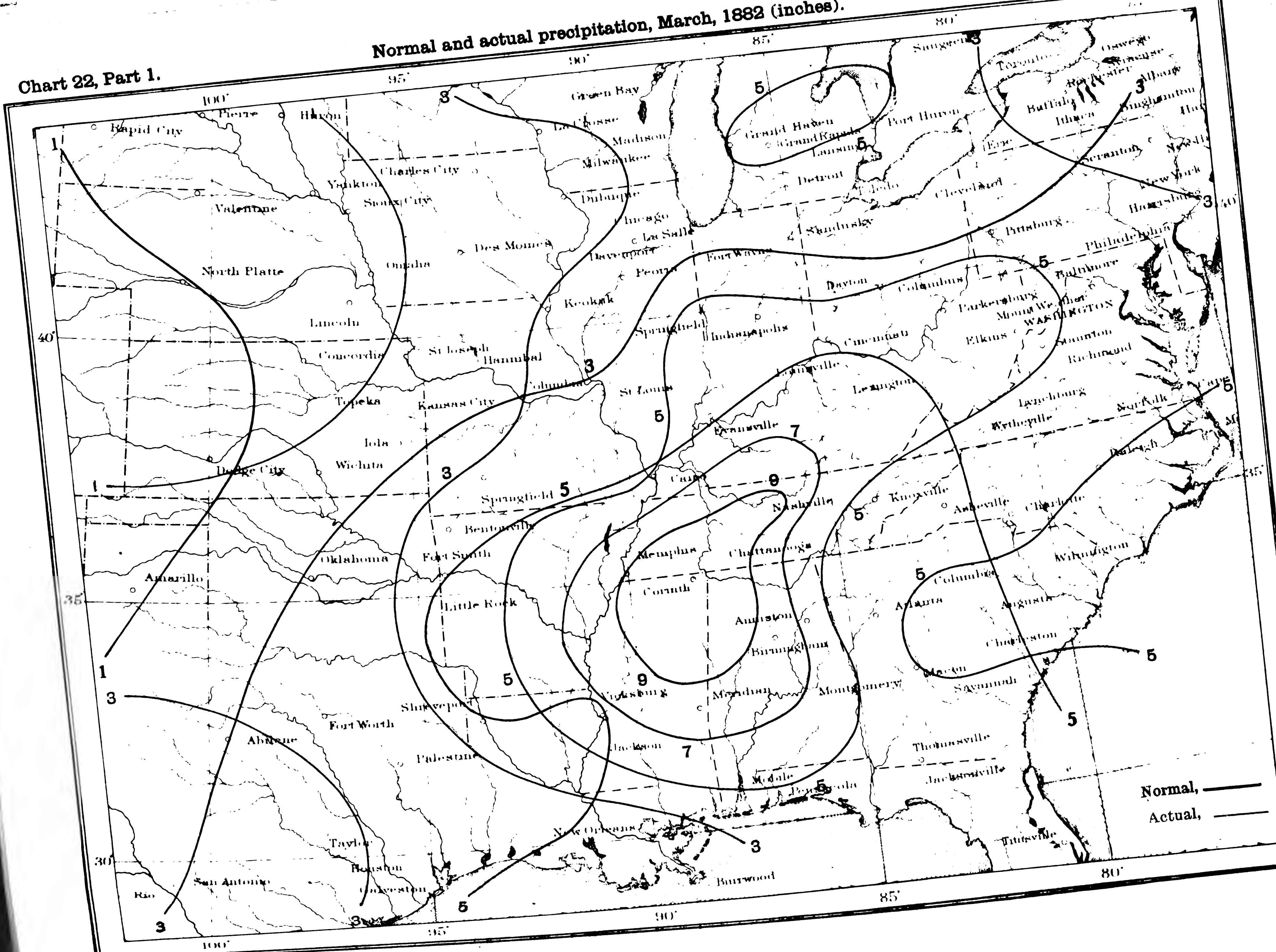

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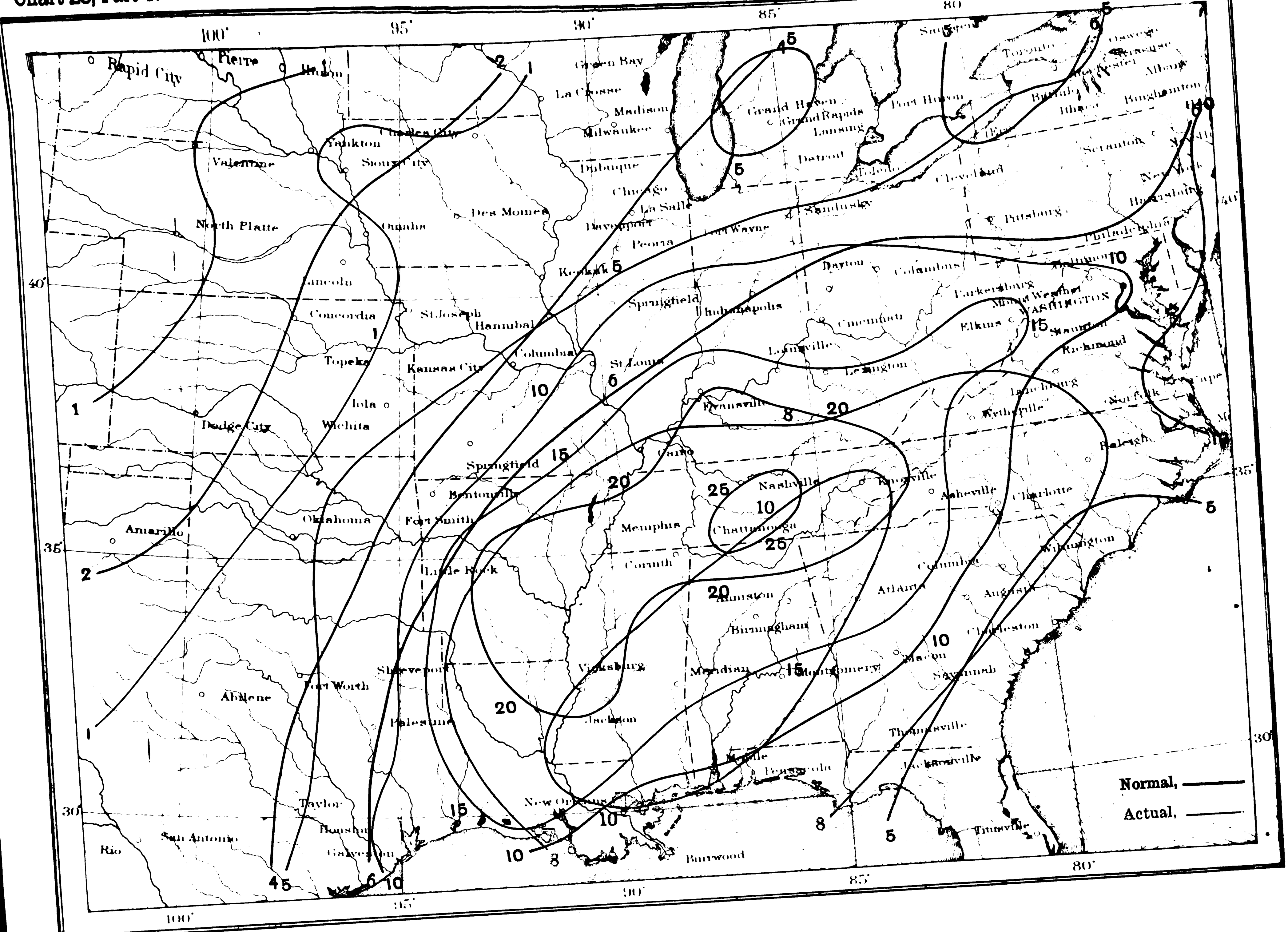

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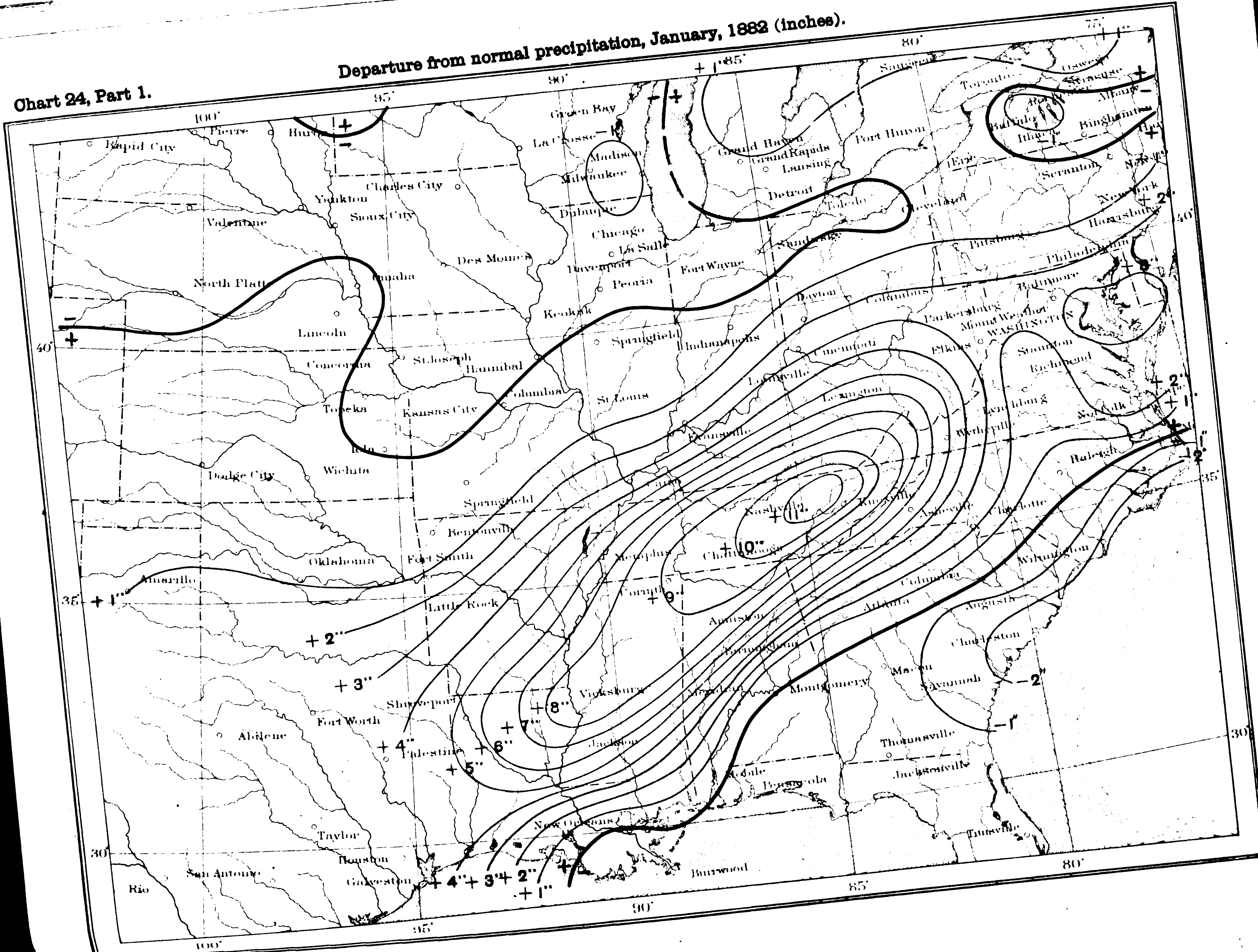

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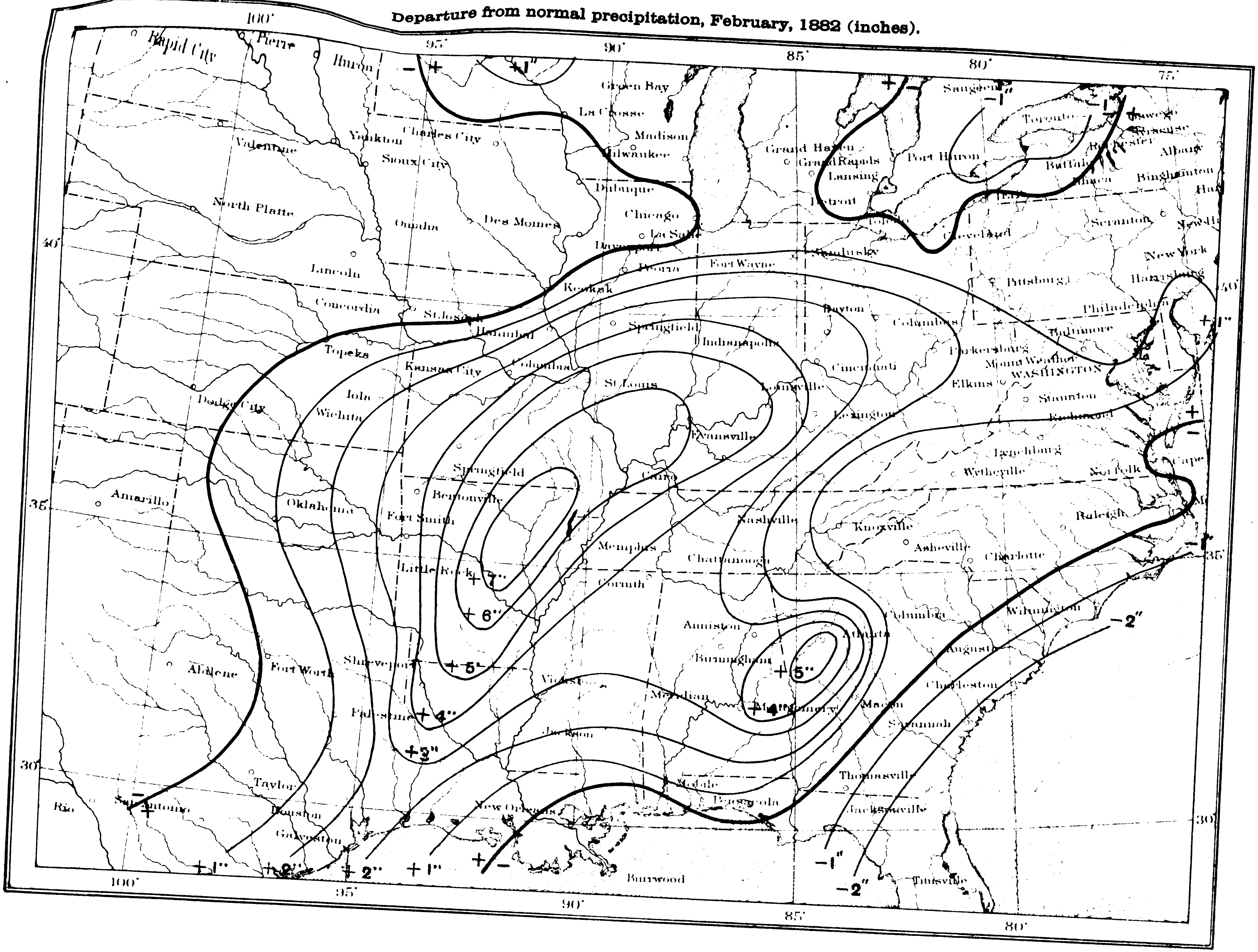

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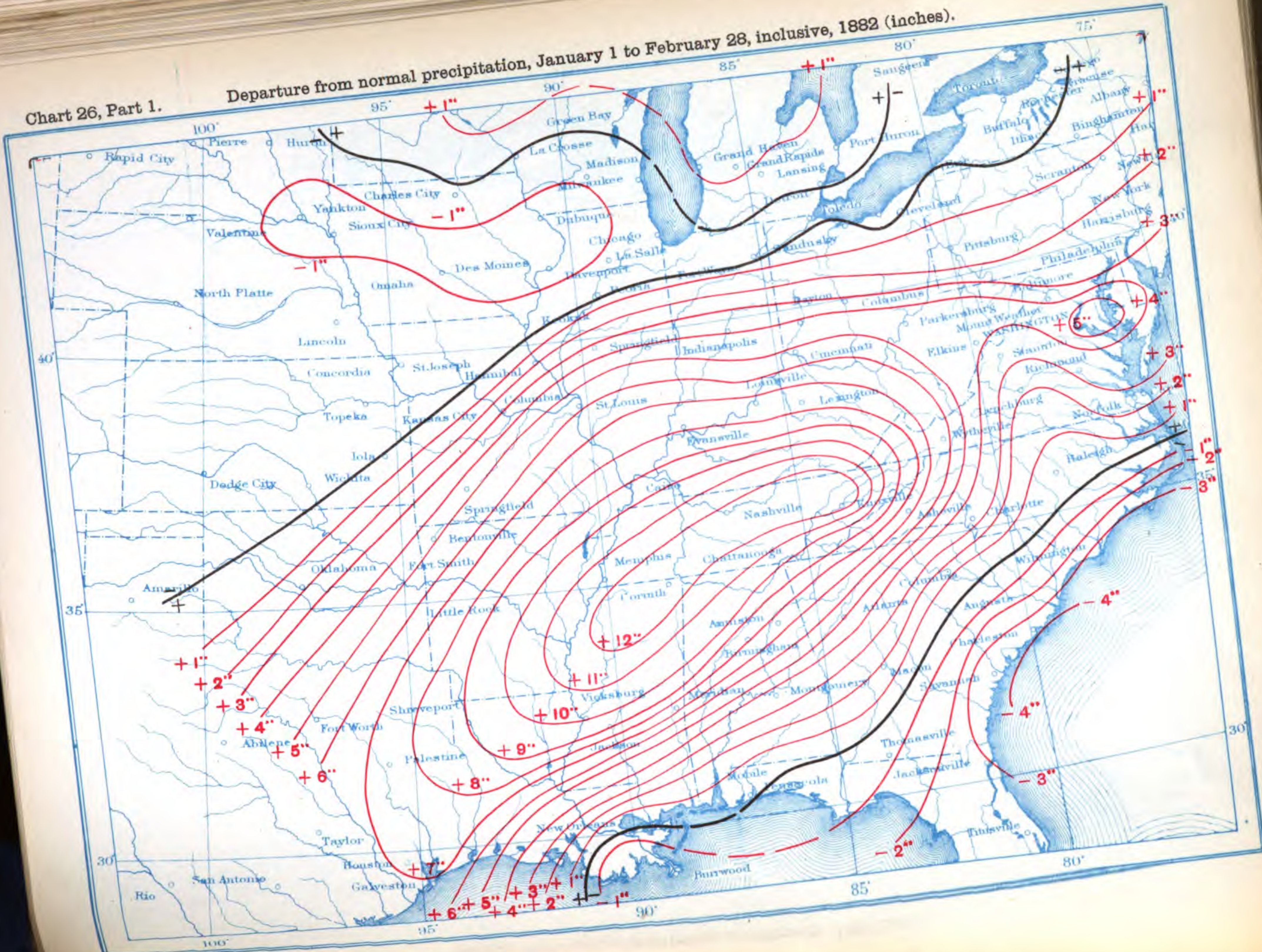

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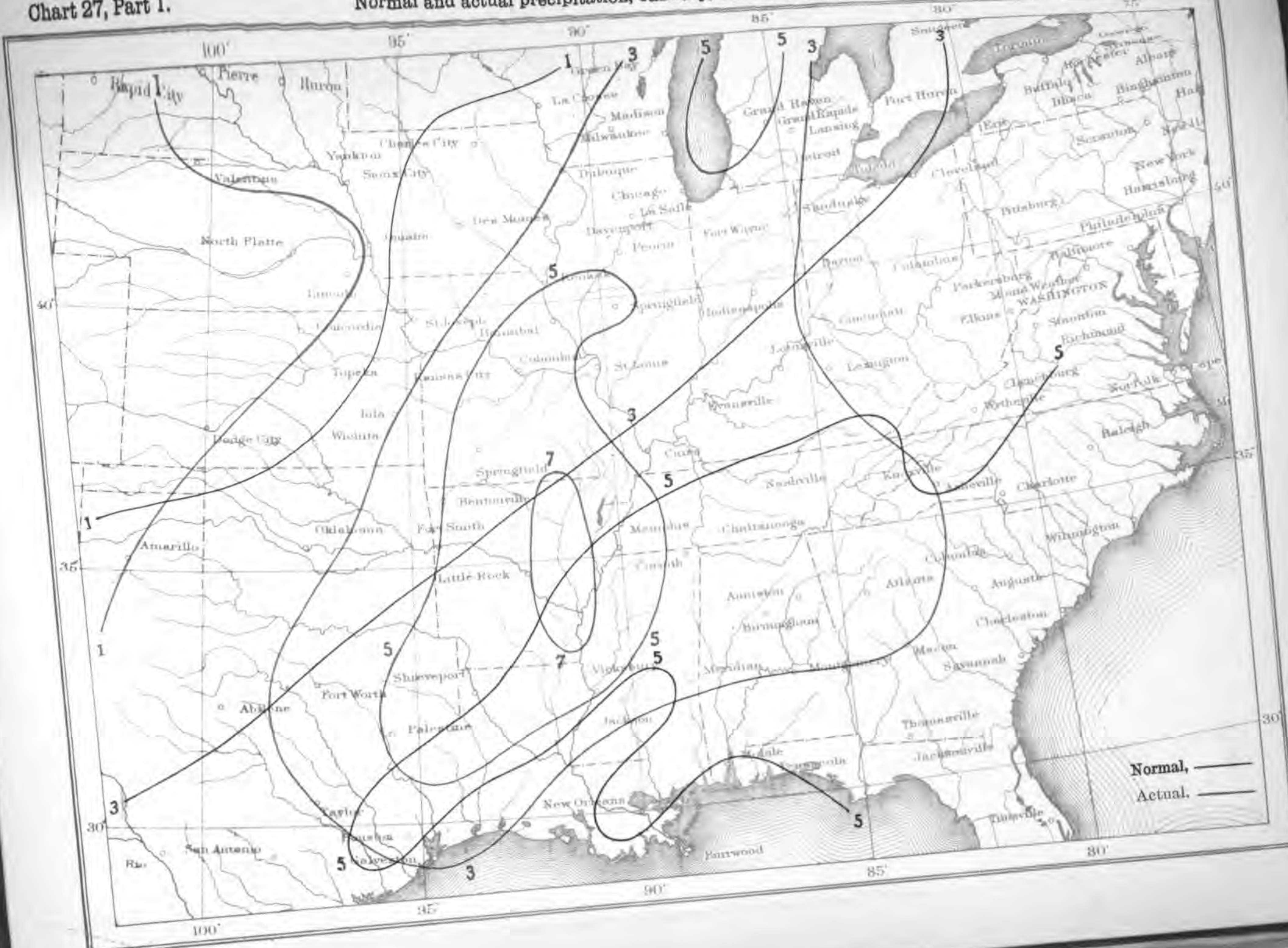

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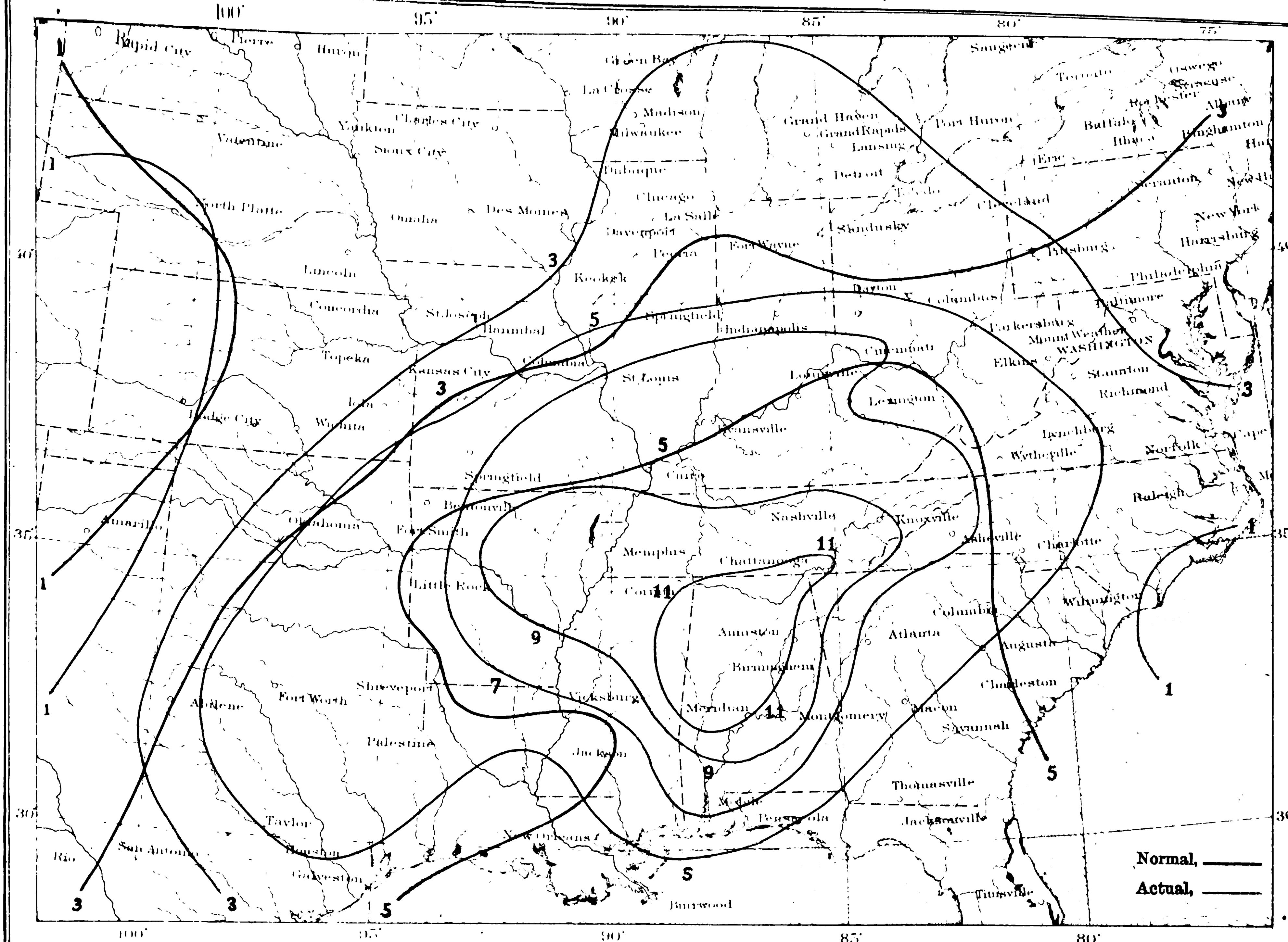

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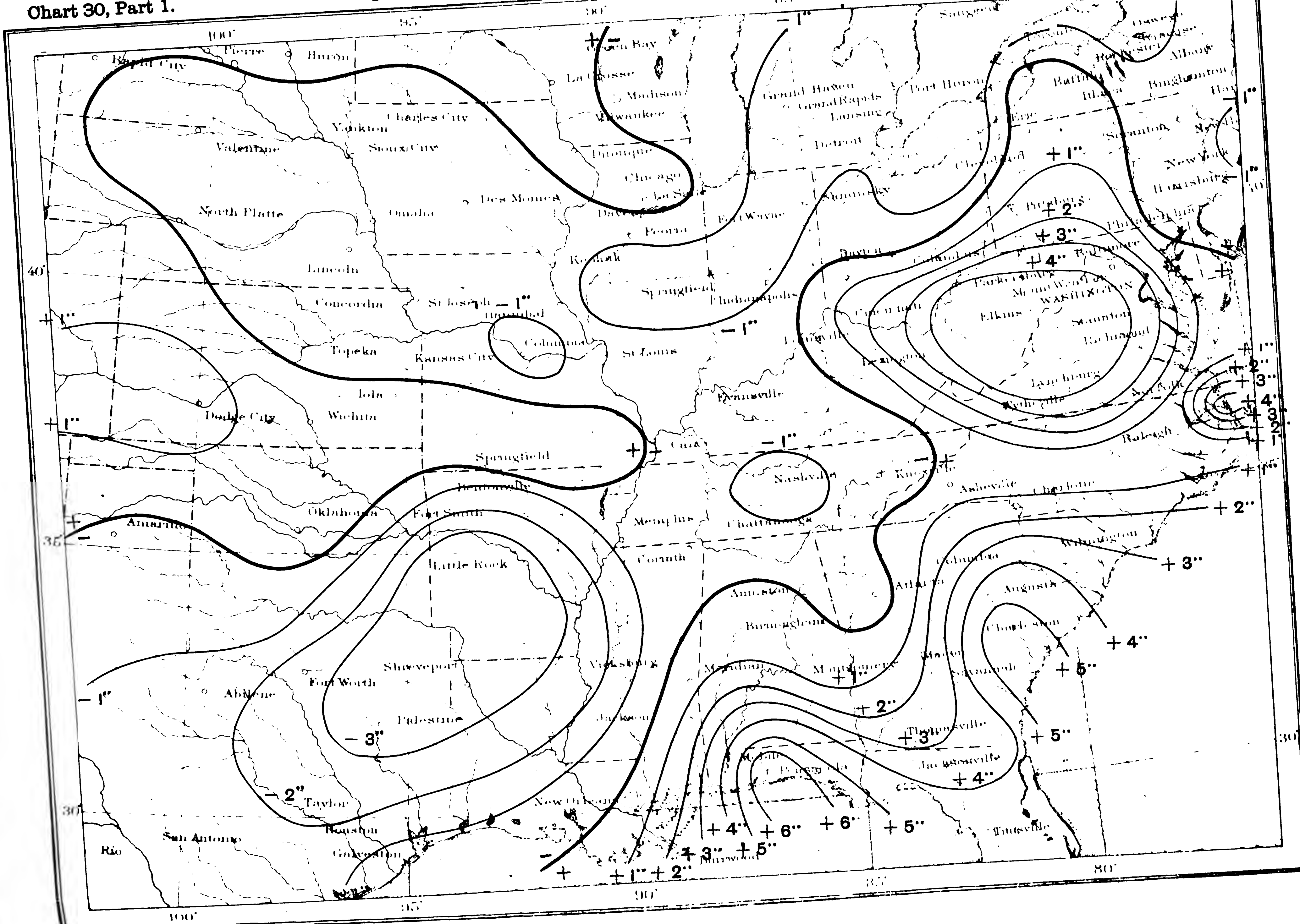

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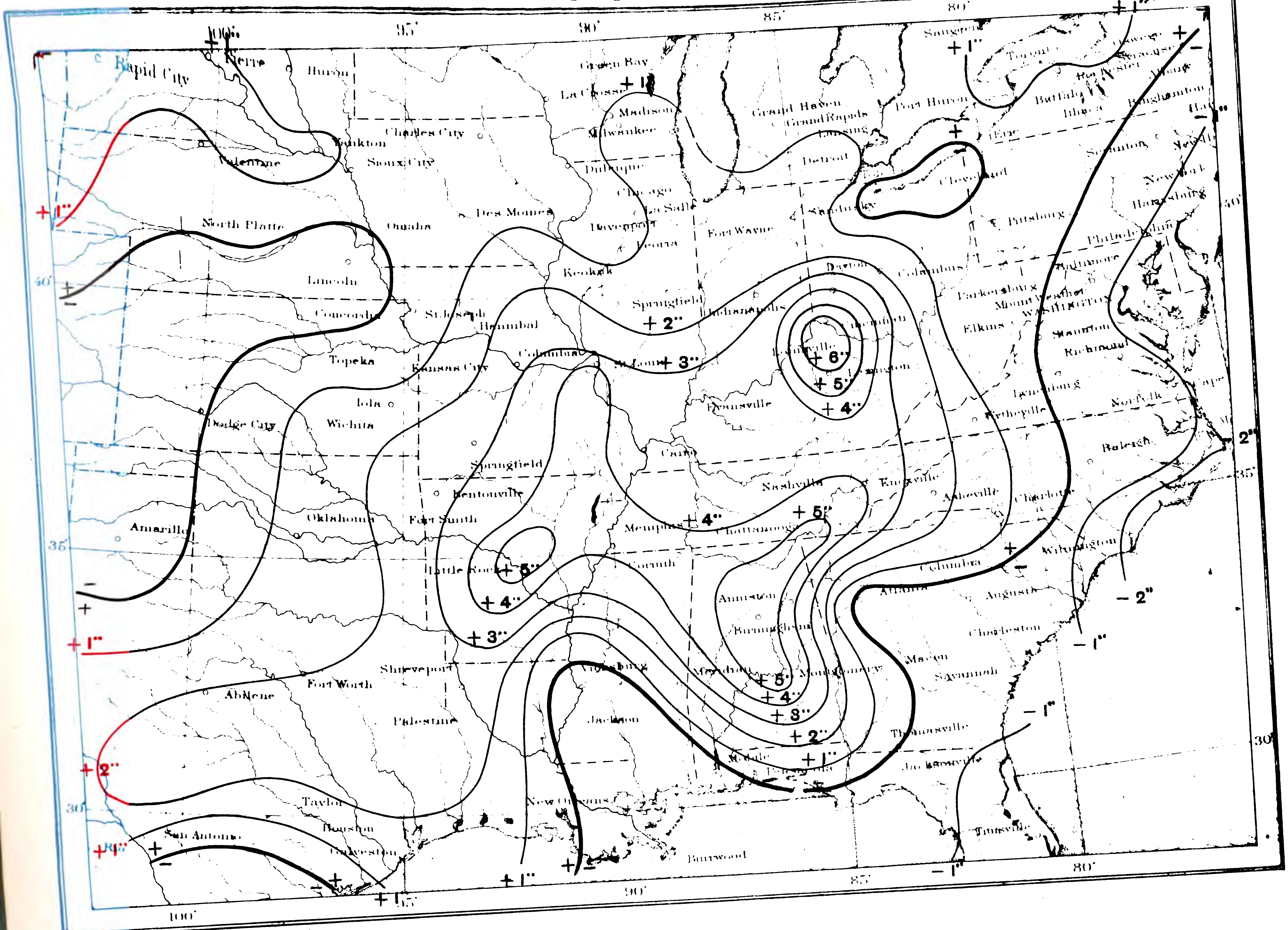

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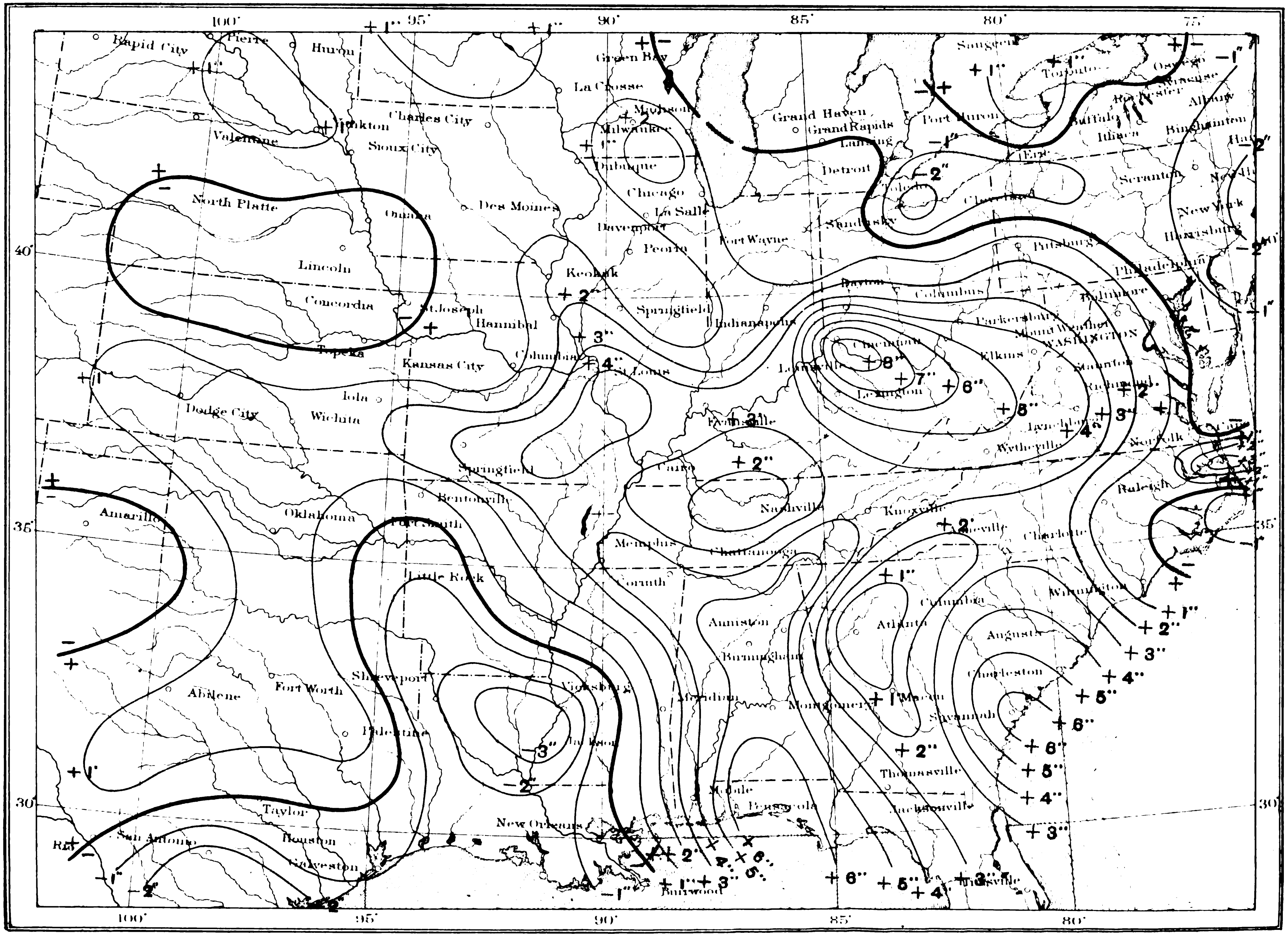

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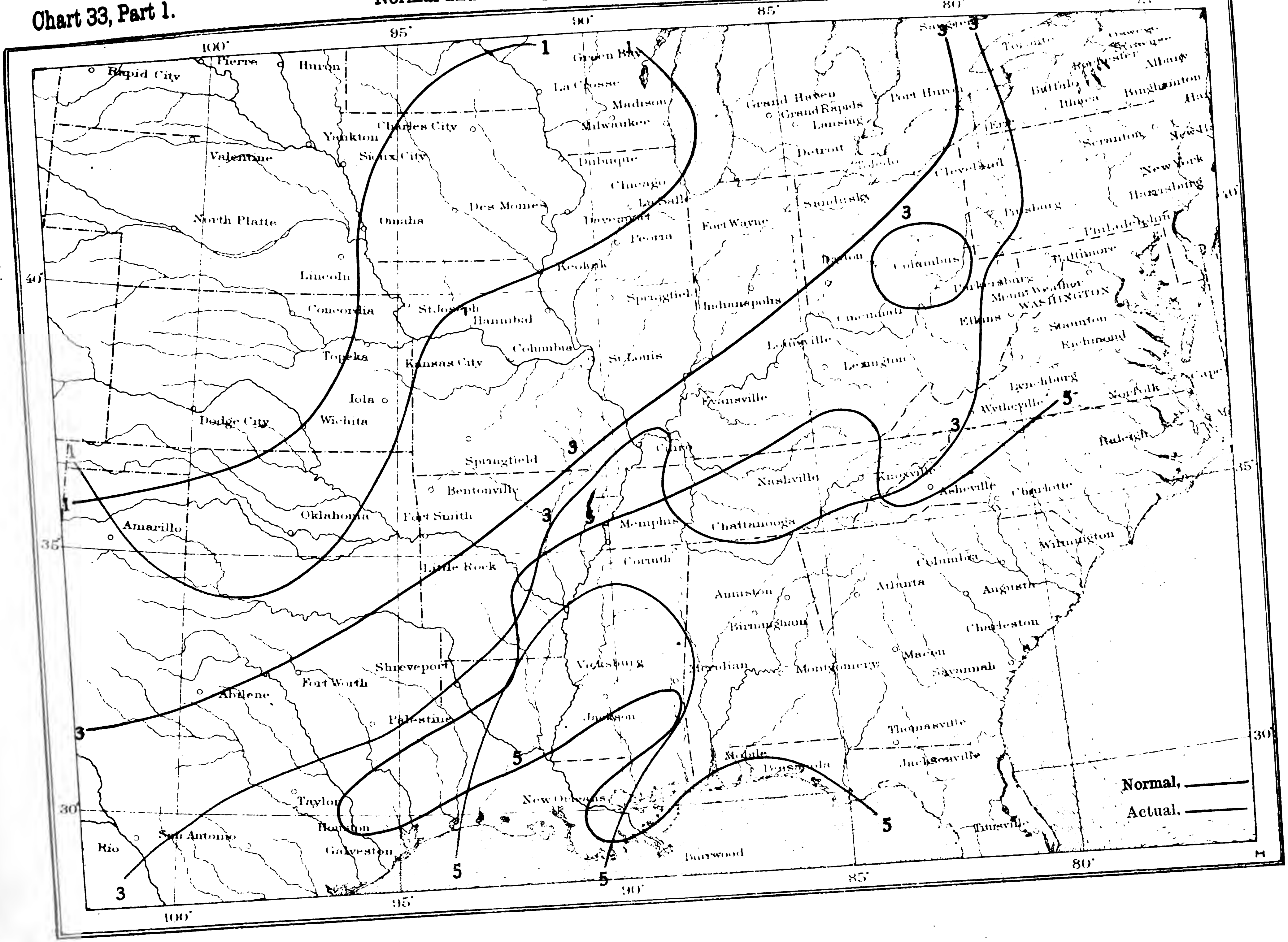

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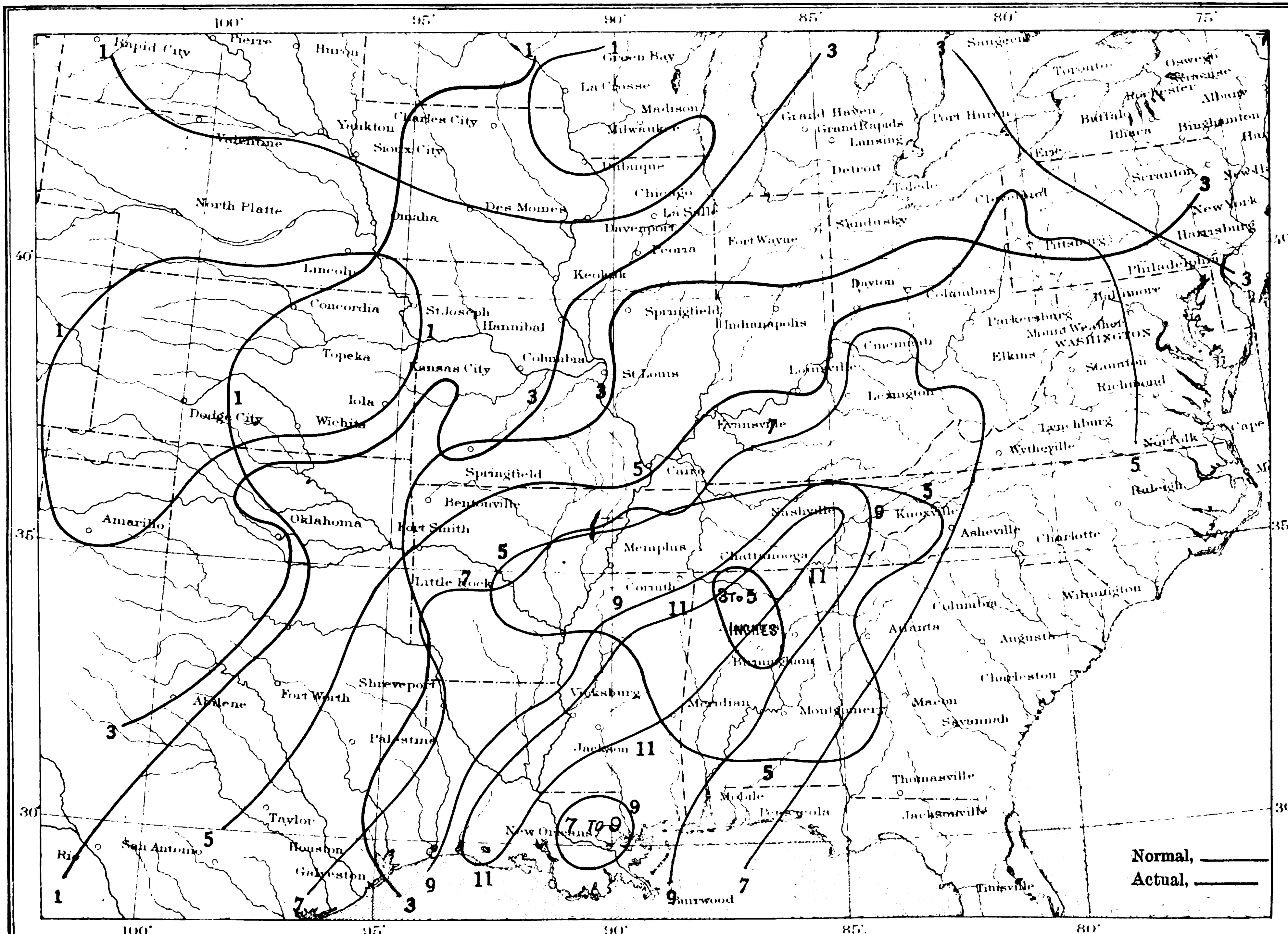

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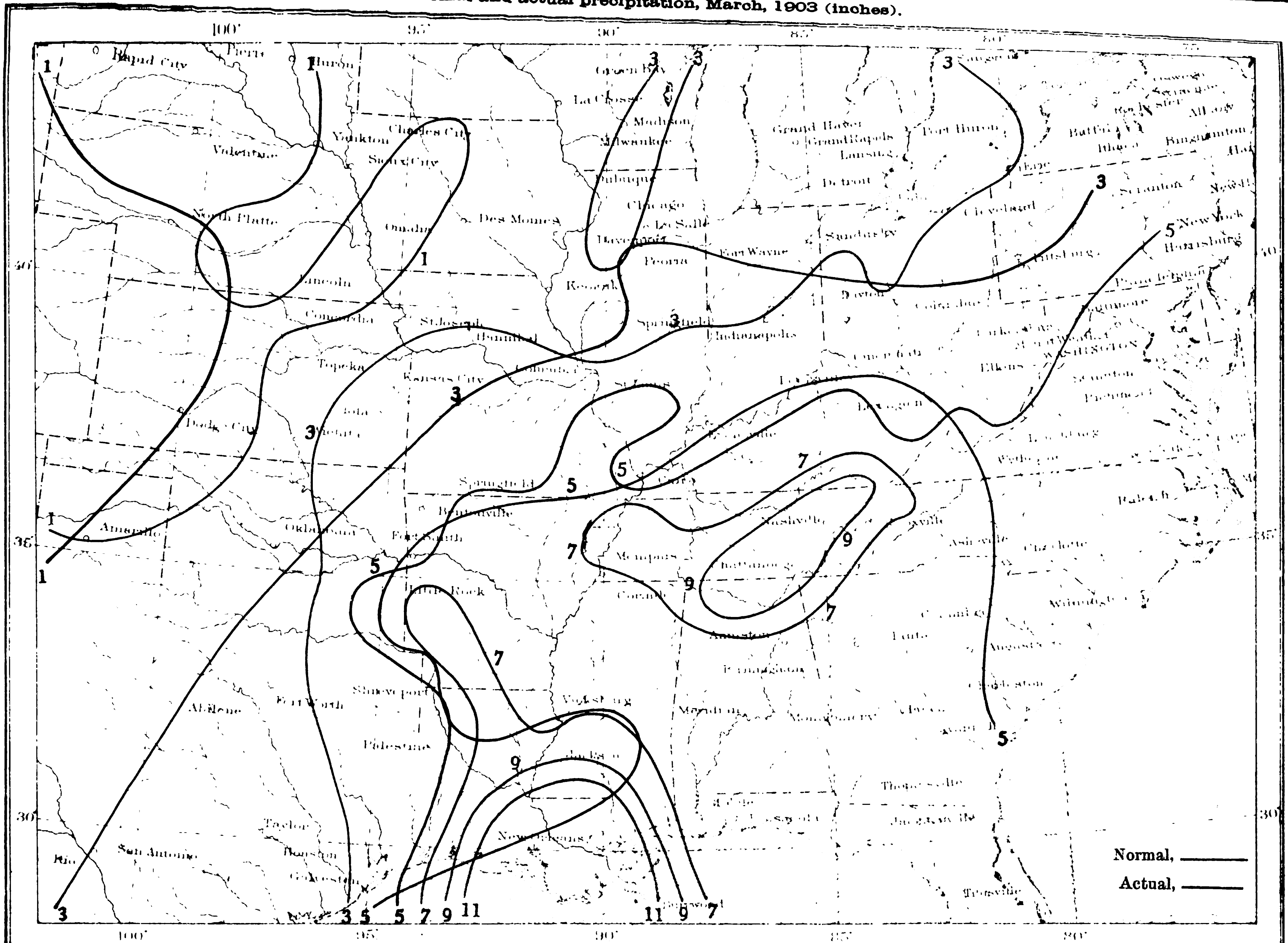

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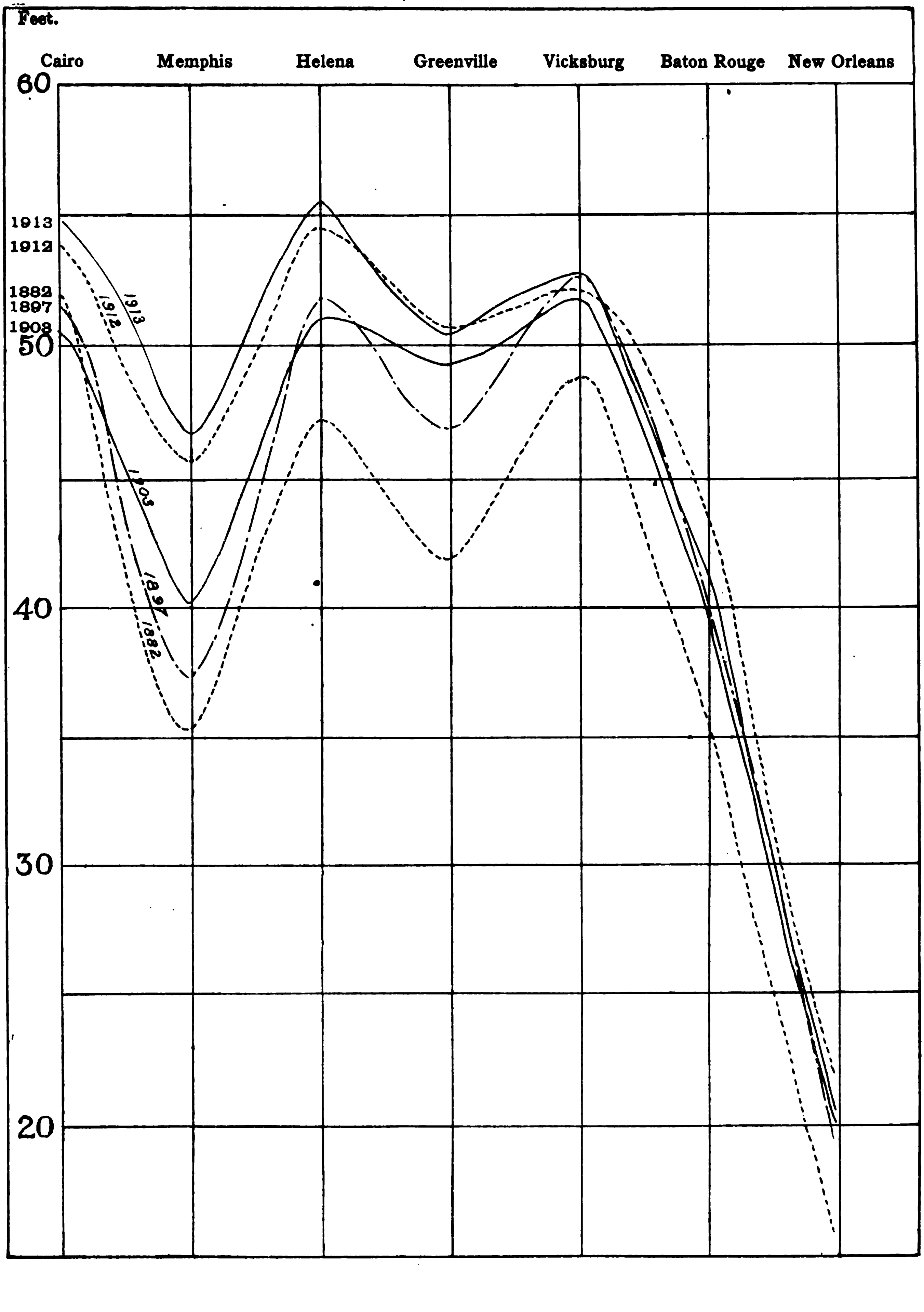

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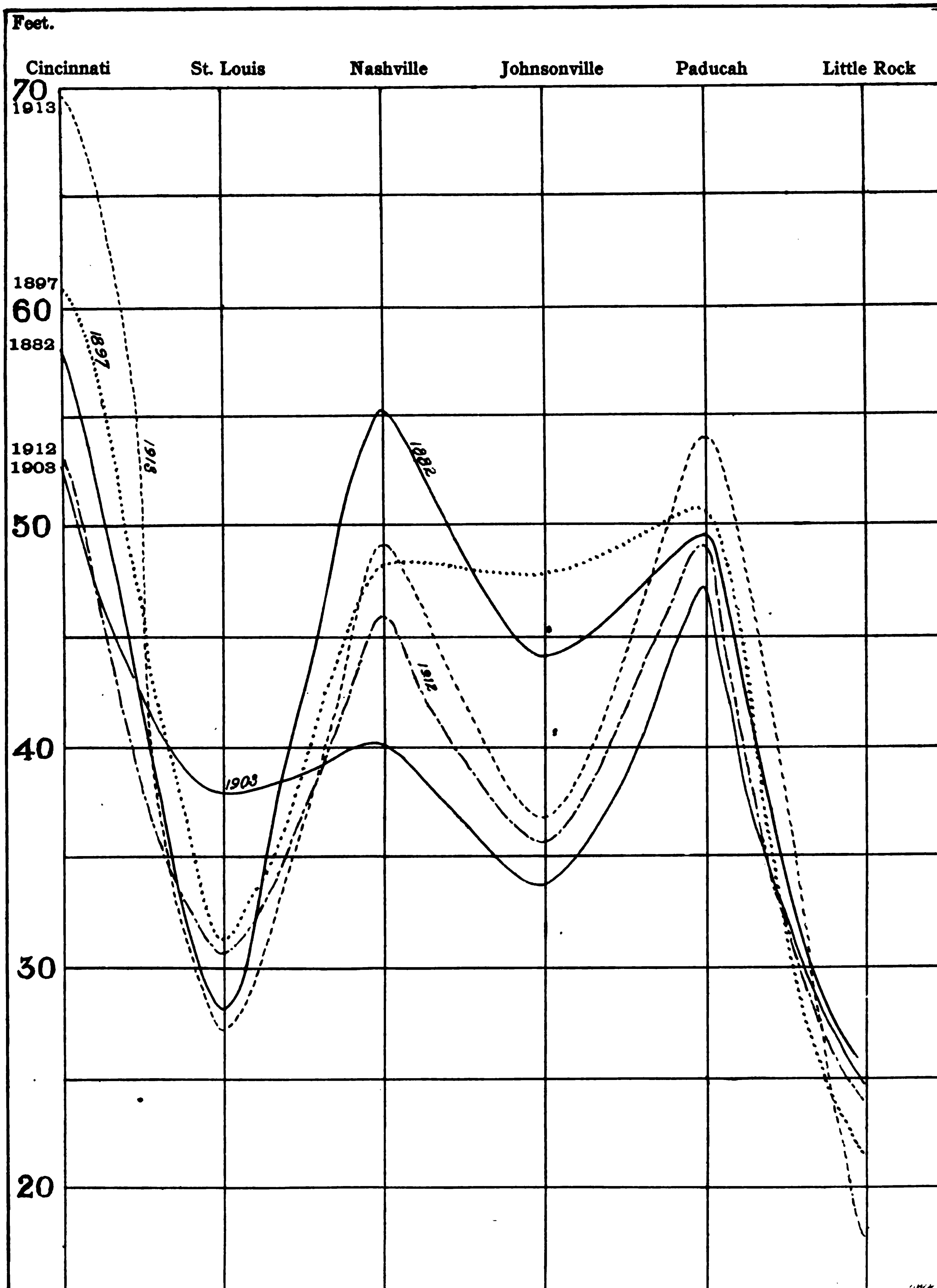

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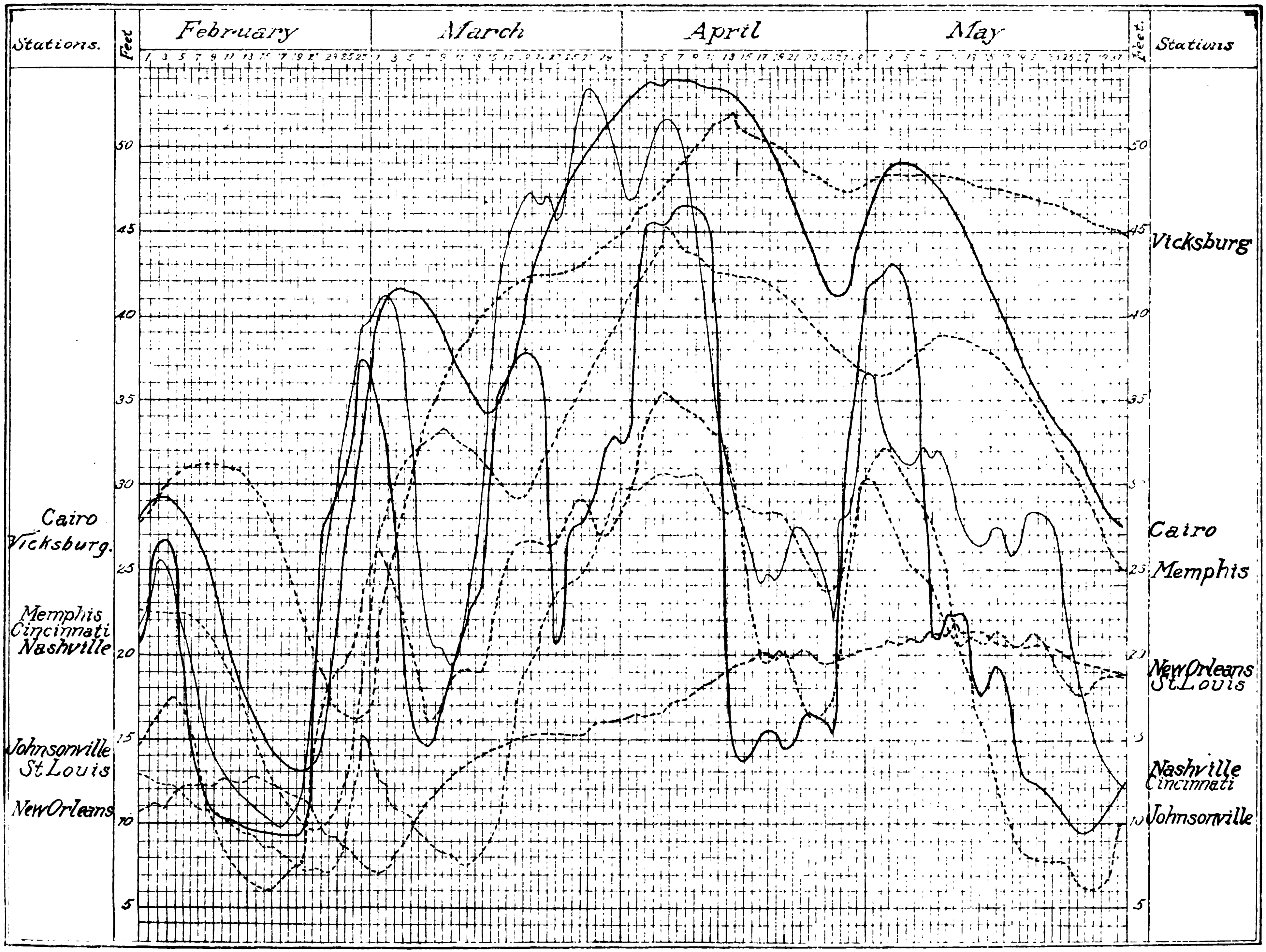

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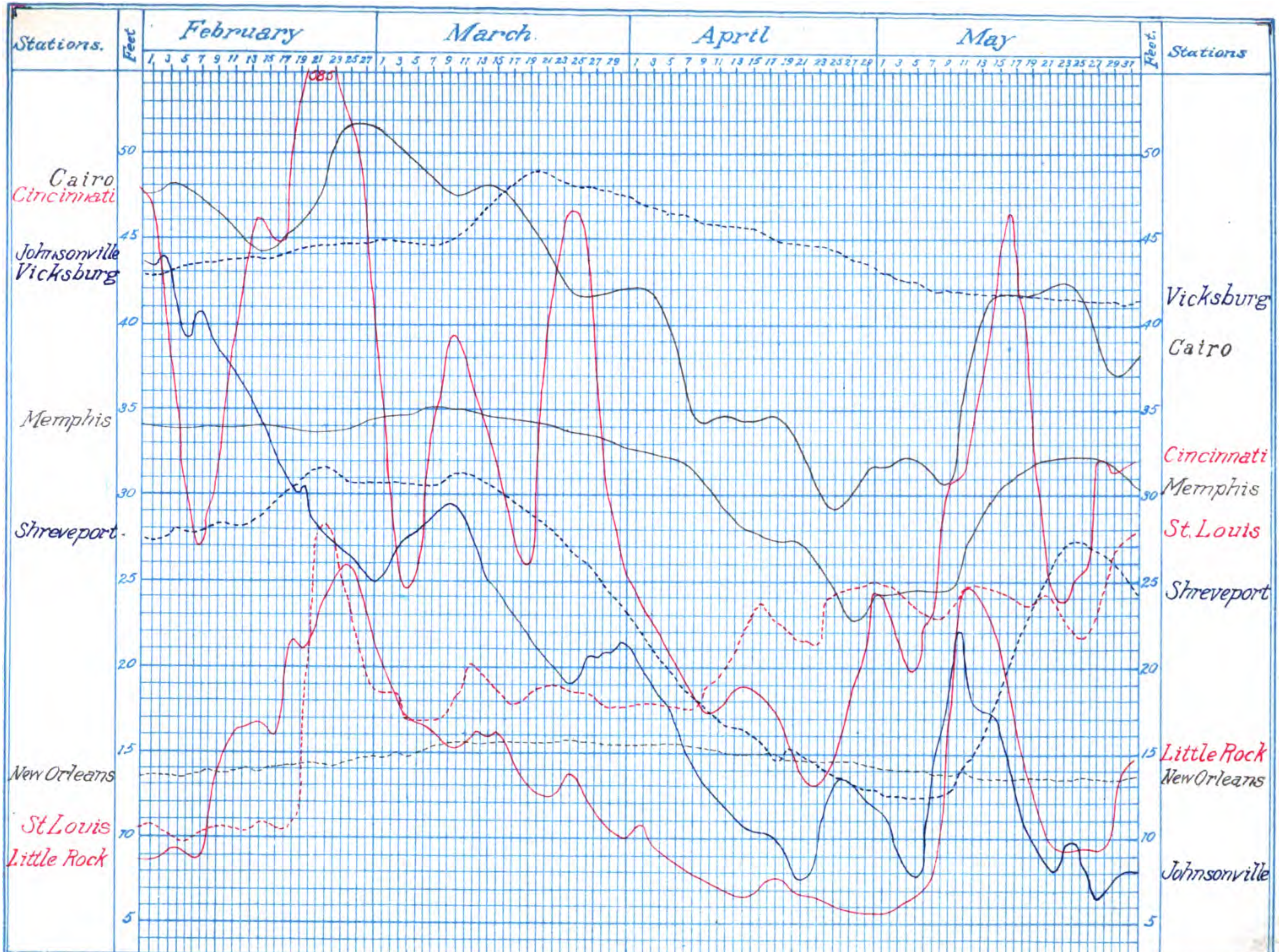

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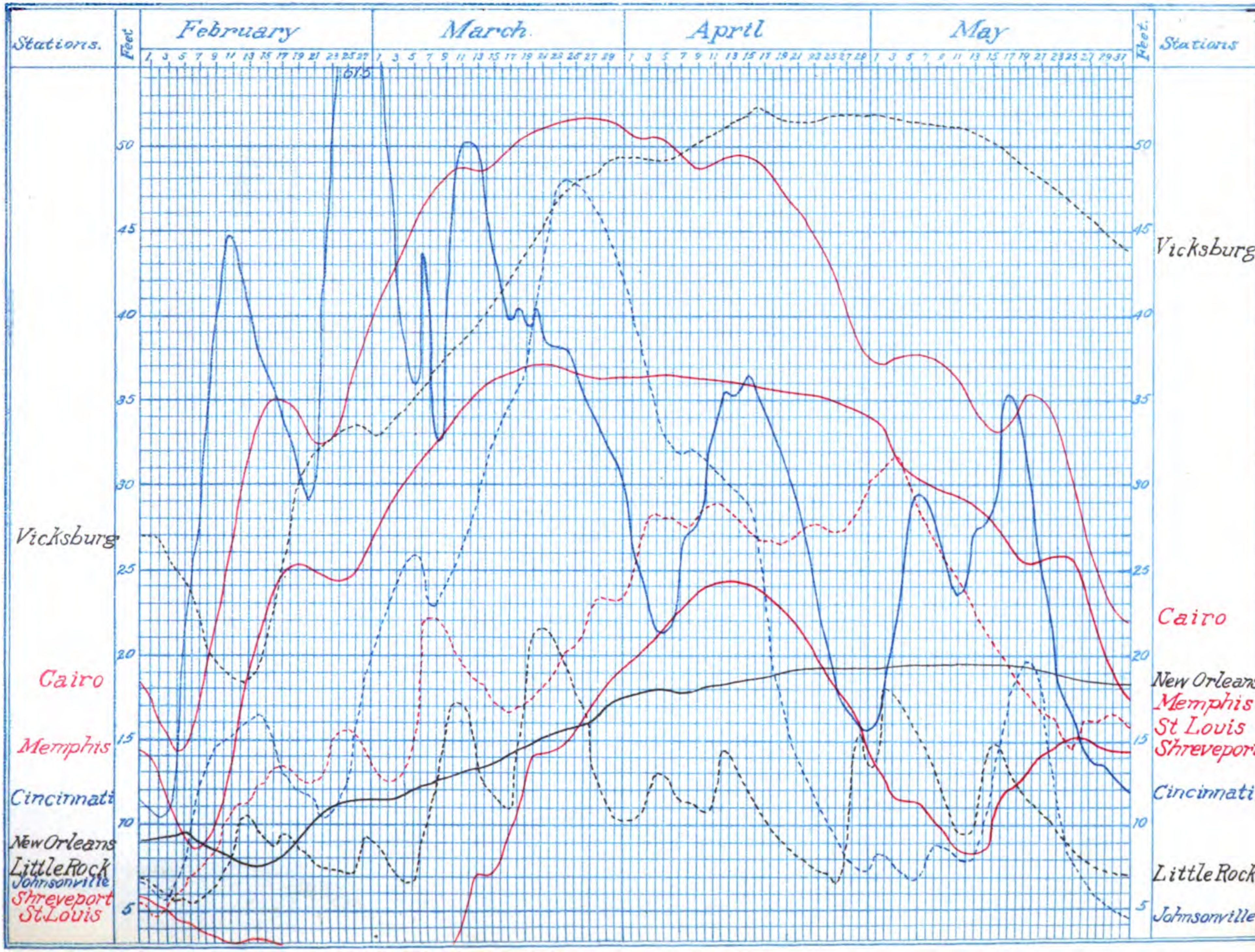

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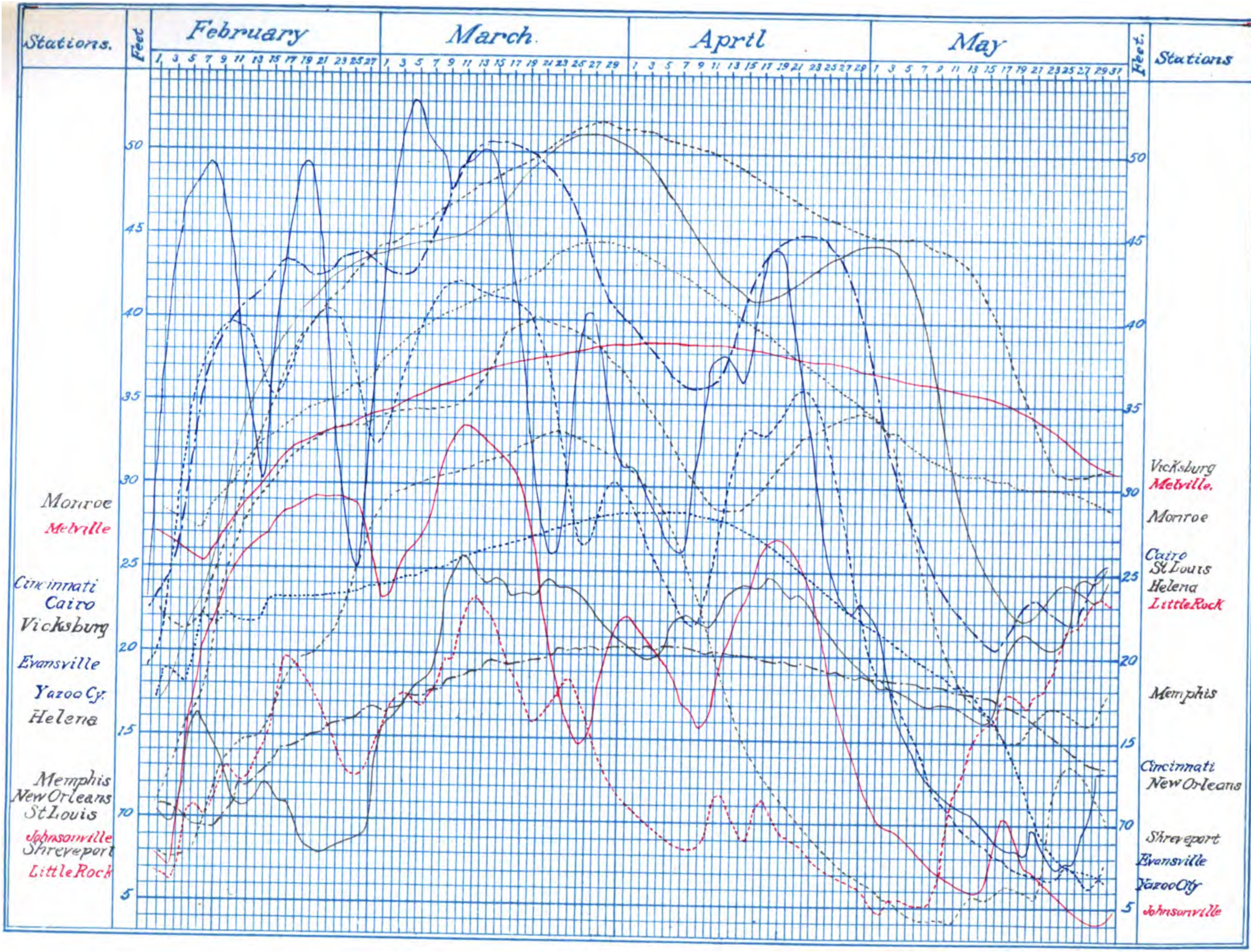

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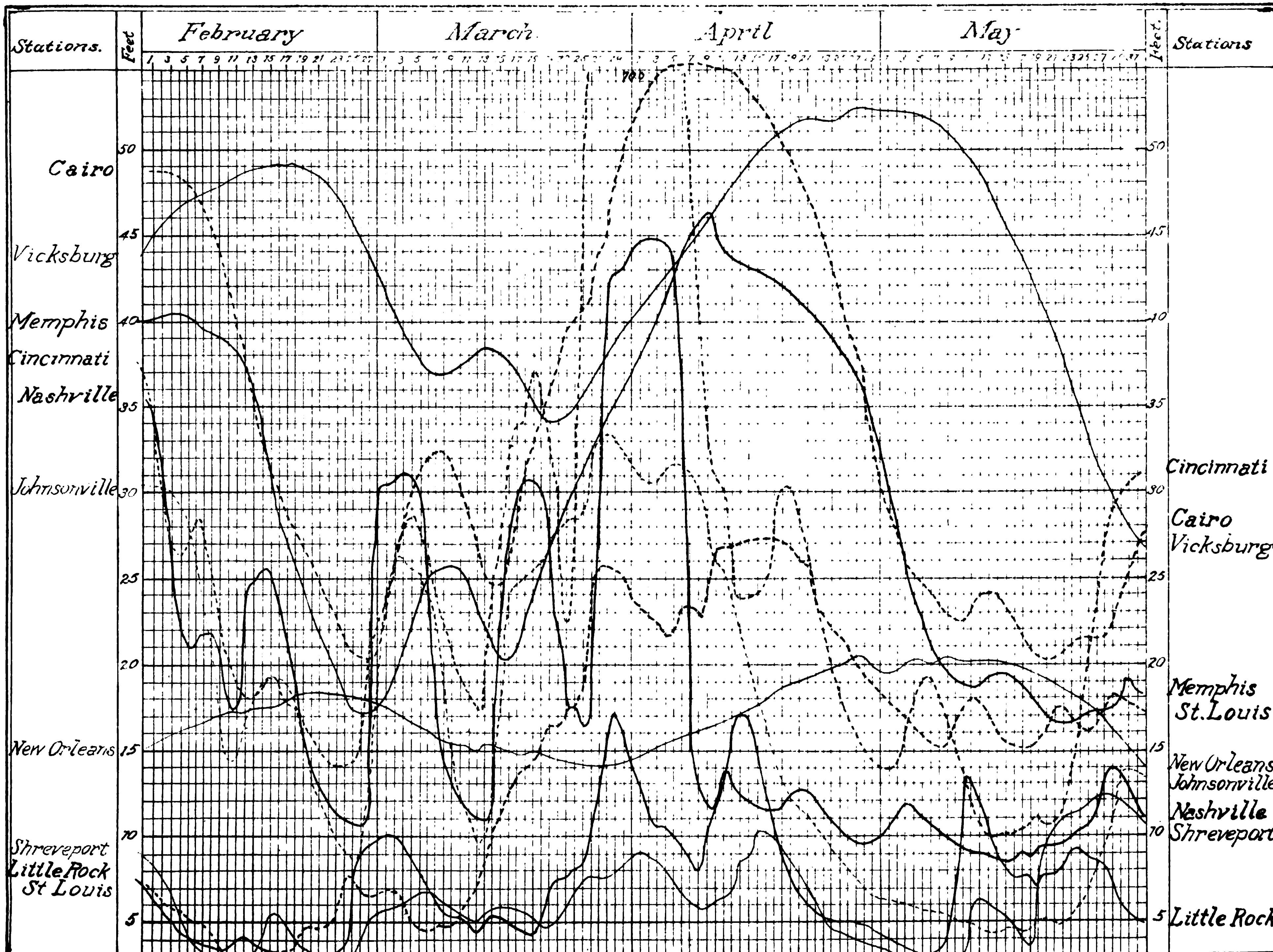

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Issued December [illegible], [illegible]

U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

C. F. MARVIN, Chief

THE FLOODS OF 1913

IN THE

RIVERS OF THE OHIO AND LOWER MISSISSIPPI VALLEYS

BULLETIN Z

BY

ALFRED J. HENRY

Professor of Meteorology

WASHINGTON

GOVERNMENT PRINTING OFFICE

[illegible]

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU, OFFICE OF THE CHIEF,
Washington, D. C., October 2, 1913.

The honorable the SECRETARY OF AGRICULTURE.

SIR: I have the honor to transmit herewith a report on the disastrous floods of March and April, 1913, in the States of Ohio and Indiana; also of the resulting floods in the Ohio and lower Mississippi Rivers, together with tables and illustrations appertaining to the same. This report has been prepared by Prof. Alfred J. Henry.

I recommend its publication as Bulletin Z of the Weather Bureau.

Very respectfully,

C. F. MARVIN, *Chief of Bureau.*

Approved.

B. T. GALLOWAY, *Acting Secretary.*

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Also to Mr. R. E. Horton, of Albany, N. Y., for a report upon the floods in the State of New York.

I am further indebted to Mr. W. C. Devereaux, in charge of the Cincinnati Weather Bureau Office, for valuable suggestions and for reading the manuscript of Floods in the Ohio River; to Herman W. Smith and Andy M. Hamrick, of the river and flood division, for valuable assistance.

ERRATA: Delete the words "Part 2" on Charts Nos. 1 to 10, inclusive.

FLOODS IN THE OHIO RIVER, 1870–1913.

By Alfred J. Henry.

The Ohio Basin.—The Ohio Basin is second in size of the six great natural divisions of the Mississippi Basin, yet it ranks first in importance in the causation of damaging floods in the larger stream. The topography of the basin in the western and northern portions is generally flat and rolling, but between those portions and the eastern and southern boundaries of the basin almost all conditions of surface contour may be found. It should be remembered that the eastern and southern boundaries, for the most part, lie along the crests of the Alleghenies and related mountain ranges, and that down the rugged western slopes of these mountains flow the streams which form the southern tributaries of such rivers as the Monongahela, the Little Kanawha, The Great Kanawha, the Big Sandy, the Kentucky, the Cumberland, and the Tennessee. On the headwaters of these rivers the slopes are steep, gradually becoming less as the lowlands are reached.

Contributing causes of Ohio floods.—The Ohio is preeminently one of the turbulent rivers of the United States among streams of its size and drainage area. There are several important reasons why this should be so. First in order of importance is the accident of geographic location considered with respect to the meteorological conditions which dominate the weather of the interior of the continent. The longer dimension of the basin extends in a southwest-northeast direction from northeastern Mississippi to southwestern New York, a distance of about 800 miles; its shorter dimension stretches from northern Indiana southeastward to northern Georgia, a distance of about 500 miles: its total area is 201,700 square miles, and practically all of this vast area lies wholly within the region of frequent and copious rainstorms which, particularly in the winter and spring, pass from Texas to New England, directly over the longer axis of the basin of the river. Moreover, the northern portion of the basin also lies within the area of rainfall produced by storms which pass across the continent from west to east over the Great Lakes. Owing to certain phases of storm development and movement not at present susceptible of satisfactory explanation, a storm passing eastward along or through the northern tier of States sometimes leaves an unsettled condition in its rear which may extend southwestward to the Gulf of Mexico, in which secondary storm centers are apt to develop and move northeastward through the lower Mississippi Valley, depositing heavy rains in both valleys. The northern portion of the Ohio Basin is, therefore, so located with respect to storm movement that it receives at times two downpours in quick succession. The torrential rains of March 23–27, 1913, illustrate this possibility, with the exception that the interval between the passage of the two storms on those dates was so short that the rainfall seemed to be, and was for all practical purposes, continuous.

Another meteorological condition occasionally develops over the interior of the continent. technically known as the formation of a barometric trough, which separates two regions of higher pressure, one to the southeast and the other to the northwest; the southeastern or Atlantic area of high pressure extends well over the ocean, and the wind movement along and in its western borders is from the south and its moisture content is naturally high. The air of the northwestern or continental area of high pressure is cold and dry, and the opportunity is therefore continually present for the cold, dry air of the northwest to underrun and force upward the lighter moist air which belongs to the Atlantic high-pressure system. The quality

or condition of immobility is largely developed in the latter, and to this quality may be attributed the long-continued rains which frequently attend "trough" pressure formations over the Ohio and lower Mississippi Valleys.

Primarily all floods are the results of falling rain or melting snow, or a combination of the two. The winter precipitation on the headwaters of the streams which take rise in the Alleghenies is mostly in the form of snow. Under favorable conditions as to temperature snow may accumulate in the mountains, and even on the lowlands, of the northern portion of the basin, until its presence becomes a menace to the dwellers in the lowlands, since there is ever present the possibility of a temporary warm spell or a warm rain occurring throughout the watershed. The transition from the lower warmer end of the basin to the upper colder portion is easily and quickly accomplished even in the heart of winter.

As a natural result of the meterological conditions described in the preceding paragraphs, the Ohio Basin has a greater precipitation than any other of the northern tributary basins of the Mississippi. Finally, among other important contributory causes are the physical features of the basin in western Pennsylvania, West Virginia, Kentucky, Tennessee, and western North Carolina and the extreme southwestern portion of Virginia, such as steep slope of stream beds, lack of surface storage, etc. The physical features are permanent and their influence upon stream flow is possible of determination. The character of the seasons, however, can not be foreseen; the necessity of being prepared for destructive floods during winter and spring is, therefore, ever present.

Fortunately, all of the causes which contribute to the formation of floods in the Ohio Basin are seldom in operation over the entire watershed at one and the same time: that is to say, all of those causes which, if operating unitedly, would form an unprecedented flood generally act disconnectedly, and thus we experience floods less severe than might be expected under a more favorable conjunction of natural causes. Thus, as regards precipitation, it may be considered as a fundamental proposition that as the area of a watershed increases the probability of rain falling simultaneously over all portions of it diminishes. The full force of the proposition is better realized if we stop to consider the result of floods converging at Cairo, let us say, simultaneously from the upper Mississippi, the Missouri, and the Ohio, and then to such a flood add the waters of the Arkansas, the St. Francis, and the Red, and we have a volume of water to combat staggering to contemplate. Such a combination of flood conditions has never been known to occur, but it is within the limits of reason to assume that atmospheric conditions favorable to a modified form of the above suggestion may occur.

Ohio floods of the last 40 years.—In the last 40 years the Ohio River has been in severe flood seven times, using the expression "severe flood" to signify a stage of 5 feet or more above the flood stage for at least three-fifths of the distance between Pittsburgh and Cairo.

The term "flood stage" is synonymous with another term, viz, "danger line," which was formerly used by the Weather Service and is still in current use in flood literature. The flood stage is a point at which the river overflows its banks and begins to damage property in proximity thereto. The flood stage at any point naturally depends on the height of the river banks above low water. At Pittsburgh it is 22 feet: Parkersburg, 36 feet; Cincinnati, 50 feet; Louisville, 28 feet; Evansville, 35 feet; and Cairo, 45 feet.

Technically, a river may be in flood when it reaches the adopted flood stage, but actually serious damage is in proportion to the height above the flood stage reached by the river. It is preferred to distinguish three classes of floods, viz, (1) technical floods or freshets, during which the river does not pass more than 1 foot above the flood stage; (2) severe floods, to signify stages from 2 to 5 feet above flood stage: and (3) great floods, to indicate the greatest recorded floods. If we take the maximum stage of water recorded at the several stations along the Ohio River as having a value of 1, we may express other floods in terms of the maximum stage; thus, 5 feet above flood stage at points between Pittsburgh and Louisville is equivalent to a stage of 0.7 to 0.8 of the maximum stage. Between Evansville and Cairo, 5 feet above the flood stage is equivalent to from 0.85 to 0.9 of the maximum stage.

Severe floods in the Ohio River occurred in the years 1882, 1883, 1884, 1897, 1898, 1907, and 1913; of these the floods of 1884, 1907, and 1913 may be classed as "great floods." Two severe floods occurred in each of the years 1907 and 1913. There were, of course, other years of flood on individual stretches of the river, and also other years when the river was in moderate flood from Pittsburgh to its junction with the Mississippi at Cairo. The subjoined table includes practically all of the severe floods, with the stages recorded at Pittsburgh, Parkersburg, Cincinnati, Louisville, Evansville, and Cairo. The criterion of a severe flood, as before stated, is a stage of 5 feet or more above flood stage, although a few stages a little short of 5 feet have been given for Cairo to complete the record of upriver floods.

TABLE I. *Ohio River floods of 5 feet and more above flood stage.*[1]

Year.	Pittsburgh. (22 feet).		Parkersburg (36 feet).		Cincinnati (50 feet).		Louisville (28 feet).		Evansville (35 feet).		Cairo (45 feet).[2]	
	Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.
1832	35.0	Feb. 10	49.5		64.2	Feb. 18	40.8		46.3			
1882					58.6	Feb. 21	37.4	Feb. 22	44.9	Feb. 24	51.9	Feb. 26
1883	28.0	Feb. 8	45.2	Feb. 10	66.3	Feb. 15	44.4	Feb. 16	47.8	Feb. 19	52.2	Do.
1884	33.3	Feb. 6	53.9	Feb. 9	71.1	Feb. 14	46.5	Feb. 15	48.0	...do....	51.8	Feb. 23
1887					56.3	Feb. 5			43.2	Feb. 8	48.5	Mar. 9
1890					56.5	Feb. 28	34.1	Mar. 3	43.9	Mar. 5	48.8	Mar. 12
1890					59.2	Mar. 25	35.5	Mar. 28	44.4	Mar. 30	48.7	Apr. 6
1891	31.3	Feb. 18	44.6	Feb. 21	57.3	Feb. 25			42.8	Mar. 2	46.2	Mar. 4
1893					54.9	Feb. 20			41.8	Feb. 24	44.9	Feb. 28
1897	29.5	Feb. 23	37.9	Feb. 25	61.2	Feb. 26	35.4	Feb. 28	43.6	Mar. 2	51.6	Mar. 25
1898	28.5	Mar. 24	47.8	Mar. 26	61.4	Mar. 29	36.3	Mar. 30	44.8	Apr. 2	49.8	Apr. 6
1899					57.4	Mar. 8			42.7	Mar. 12	46.2	Mar. 30
1902	32.4	Mar. 1							40.0	Mar. 11		
1903	28.9	..do....							42.4	...do....	50.6	Mar. 15
1904	30.0	Jan. 23	42.0	Jan. 26								
1905	29.0	Mar. 22	42.4	Mar. 23								
1907			40.1	Jan. 21	65.2	Jan. 21	41.4	Jan. 22	46.2	Jan. 24	50.4	Jan. 27
1907	35.5	Mar. 15	51.6	Mar. 16	62.1	Mar. 18	36.0	Mar. 20	43.8	Mar. 23	46.2	Mar. 24
1908	30.7	Feb. 16	41.2	Feb. 18					41.5	Mar. 14		
1909							33.0	Feb. 27	43.2	Mar. 1	47.3	Mar 17
1912									42.6	Mar. 31	54.0	Apr. 6
1913	31.3	Jan. 9	45.1	Jan. 13	62.2	Jan. 15	39.5	Jan. 14	46.7	Jan. 19	48.9	Jan. 26
1913	30.4	Mar. 28	58.9	Mar. 29	70.0	Apr. 1	44.8	Apr. 2	48.3	Apr. 1	54.8	Apr. 4,7

[1] All of the stages in the above table except those of the 1832 flood are from observations by the Weather Bureau. The 1832 stages have been collected from various sources and are believed to be authentic.
[2] Some stages less than 5 feet above flood stage are given to complete the record of upriver floods.

In the forty-odd years considered, the river at Pittsburgh was 5 feet or more above the flood stage on 13 separate occasions. Six of these floods continued throughout the course of the river to Cairo. The remaining seven, for one reason or another, dwindled away on the lower reaches of the river. Prominent among the causes of the decay of a flood is a lack of synchronism between the flood wave that is passing downstream and the output of the lower tributaries. There may have been sufficient precipitation over the watershed to cause a serious flood, but if the lower tributaries put out their quota of water either before or after the passage of the flood wave, the latter is much flattened. One of the most interesting cases of flood decay is that of the March (1907) flood, which gave the highest water ever recorded at Pittsburgh, Pa., a stage of 62.1 feet at Cincinnati, yet the river at Cairo barely passed the flood stage of 45 feet, the final reading being 46.1 feet. The causes of this apparent anomaly are as follows: The excess water at Pittsburgh and along the upper reaches of the stream was due to a snow covering of from 4 to 8 inches which overlaid the watersheds of the Conemaugh, Kiskiminetas, and Youghiogheny Rivers. Rain and warm weather combined caused the greater portion of this snow to melt and run into the rivers and small streams, but the run-off from West Virginia rivers and other tributaries farther downstream depended entirely upon rainfall

and was naturally not extraordinary, since the snowfall which caused the great run-off in the Pittsburgh district was not widespread. As a consequence the volume of water entering the river from its southern tributaries was not sufficient to maintain the stream at record-breaking stages. Another factor which must be taken into consideration when estimating the Cairo stage which should result from an upstream flood wave is the stage of the Mississippi River at Cairo at the time the flood waters of the Ohio discharge into it, since a full Mississippi has the effect of backing up the Ohio and causing a higher reading on the Cairo gage than the same volume of water would with the Mississippi at a low stage. In the March (1907) flood in the Ohio, the Mississippi was considerably lower than during the January flood of the same year. The details of the above-named flood illustrate the necessity of making a separate study of each flood, and particularly as to the circumstances of its origin and development.

Ohio floods by groups.—For convenience of discussion we may assign severe Ohio floods to one of the three following groups according to their origin: First group; floods in midwinter and spring caused by extensive and continued rains during an open winter. The flood of January, 1913, is typical of this group. Second group; floods caused by a short period of rain coming in conjunction with a midwinter thaw. The February (1884) flood is typical of the second group. We are compelled to make a third group, of which we have the single example of March, 1913. The third group therefore consists of floods caused by torrential rains extending over a comparatively short period, 72 to 96 hours. Other floods partake of some of the characteristics of each group and are therefore difficult of classification. The melting of the winter's snow is generally a factor, but its influence sometimes is practically negligible.

Individual Ohio floods before the period of systematic observations.—We now mention very briefly Ohio floods within historic periods.

Flood of 1806: The Ohio at Pittsburgh reached a stage of 33.9 feet. Independent confirmation of this flood may be found in "History of Clarion Co., 1887," where mention is made of a great flood in Red Bank Creek in 1806. Red Bank is one of the eastern tributaries of the Allegheny River, which it enters south of the Clarion River.

Flood of 1832: This flood furnished a stage on the Pittsburgh gage of 35 feet, which endured as the highest of record for 75 years; the flood was caused by rain falling upon frozen ground, melting what snow there was and running off as fast as it fell. The 1832 flood was of considerable magnitude at Cincinnati and ranks as one of the great floods at that place. Maximum stages reached by this flood at Louisville, Ky., and Evansville, Ind., are given in Table I, and the following comparative statement of flood crests in early times is due to Mr. Adam Crozier, one of the early cooperating observers of the Smithsonian Institution and later of the Signal Service.

Speaking of the flood of 1882, he says, under date of February 22, 1882:

The Ohio River reached its highest point here (35 miles below Louisville) to-day. Compared with that of former great floods it was as follows: Thirty-four inches below the flood of 1847; 33 inches above the flood of 1853; and 1 inch above the flood of 1867.

Inasmuch as the 1847 flood is said to have been 2 feet under that of 1832, the last-named flood must also be counted among the first magnitude floods in the lower stretches of the river, although it has been overtopped by the floods of 1883, 1884, 1907, and 1913.

Flood of 1847: This was a severe flood at Cincinnati and was probably due to floods in the West Virginia and Kentucky tributaries, since the stages both above and below Cincinnati indicate a moderate flood only.

There were also floods in the early fifties and the early sixties, but little definite information of them has been preserved beyond a record of the maximum stages at Pittsburgh and a few other upriver points.

Floods of the later period.—The records of the Army Engineers and the Signal Service, now Weather Bureau, include daily river stages at principal points along the Ohio from 1870

to date. At Pittsburgh and Cincinnati daily gage readings are available for an earlier period; otherwise the record begins in 1870. In the decade 1870–1880 there were no general floods of consequence, but, coincident with an increase in precipitation in the early eighties, a series of floods set in beginning in 1882, continuing through 1883, and culminating in the great Ohio flood of 1884. In the same decade there were also minor floods in the lower part of the river in 1887.

In the decade 1890–1900 there were general floods in the years 1897 and 1898, but they were not unusually severe.

In the 10 years 1900 to 1910 there were numerous minor floods in the upper stretches of the river and also two severe floods in 1907.

A severe flood in the lower stretches of the river in 1912 was followed by a general flood in January, 1913, and a greater flood in March–April of the same year.

To recapitulate: The Ohio River during the last forty-odd years has been in decided flood in its entirety seven times; it has been in discontinuous flood much more frequently; thus at Pittsburgh in the same period the number of times with a stage of 5 feet above the adopted flood stage of 22 feet was 13; owing to the fact that some of the most important tributary streams in flood causation enter the Ohio between Pittsburgh and Cincinnati, it would probably be a better criterion of great floods to use the stages recorded at Cincinnati instead of Pittsburgh. Table I shows that a stage of the river at that place 5 or more feet above the flood stage, 50 feet, has occurred fifteen times; of these, however, four, viz, those of 1891, 1893, 1899, and the second flood of 1907, did not reach Cairo with an excess of at least 3 feet above flood stage, and must be classed as discontinuous or decaying floods; 11 of the 15 floods, however, continued to Cairo with little or no abatement, and that number is believed to represent the flood frequency during the period 1871-1913. The years in sequence are 1882, 1883, 1884, 1890 (2), 1897, 1898, 1907 (January), 1913 (2), and the classification according to that herein proposed is as follows:

Group 1: Floods due to accumulated rains in January, February, and March	7
Group 2: Floods due to winter rains in conjunction with a thaw	3
Group 3: Heavy rains within a few days	1
Total Ohio floods, Cincinnati to Cairo	11

The great majority of floods, therefore (7 out of 11), were due to heavy rainfall in the Ohio Basin; severe floods occur almost invariably in the months of January, February, and March, sometimes lapping over into April.

Passing now to a consideration of the floods of 1913, it may be remarked at the outset that the atmospheric conditions during January were unusually conducive to flood formation. A flood of moderate severity passed down the Ohio River beginning at Pittsburgh, Pa., on January 9, reaching Cairo 17 days later, and New Orleans, La., by February 23—45 days from Pittsburgh. The small table shows the progress of the January flood from Pittsburgh to New Orleans.

Ohio and Mississippi River flood of January–February, 1913.

Stations.	Flood stage.	Crest stage.	Date January, 1913.	Number of days above flood stage.	Stations.	Flood stage.	Crest stage.	Date February, 1913.	Number of days above flood stage.
	Feet.	*Feet.*				*Feet.*	*Feet.*		
Pittsburgh	22	31.3	9	4	Memphis	35	40.5	3	25
Parkersburg	36	45.1	13	8	Vicksburg	45	49.0	16-18	22
Cincinnati	50	62.2	15	10	Natchez	46	48.7	20	21
Louisville	28	39.5	14	11	Baton Rouge	35	37.2	22	19
Evansville	35	46.7	19	27	Donaldsonville	28	29.3	22	17
Cairo	45	48.9	26	21	New Orleans	18	18.4	23	10

The origin of the March, 1913, flood.—The meteorological conditions which led up to the disastrous floods of March, 1913, in Ohio and Indiana, have been reported upon elsewhere by the writer (Monthly Weather Review, March, 1913); suffice it for our present purpose to summarize them very briefly in the following paragraph:

An unprecedented amount of rain fell over the States of Ohio and Indiana in the space of 72 hours, or from the afternoon of March 23 to the afternoon of March 26, 1913. The rain continued over these and adjoining States with practically no intermission, although at a lower rate of intensity during the 27th, the aggregate amount for the four-day period being absolutely without precedent for a like period over a considerable portion of the watershed of the northern tributary streams in Ohio and Indiana. The extension of the region of rainfall over the southern tributaries of the Ohio on March 26 and 27 made a flood in the streams of that region certain.

EXCESSIVE PRECIPITATION IN OHIO.

In order to make a comparison of the accumulated amounts of precipitation in the case of the March, 1913, floods with previous storms, we have examined the continuous record of daily precipitation for Cincinnati, Ohio, for the period 1871–1913. The criterion on which the table below was formed was the occurrence of at least 1 inch of precipitation in 24 hours; that amount must have occurred at least in 1 of the 24 hours considered, hence each group of dates represents the occurrence of at least 1 inch in 24 hours. If no rain fell on the day immediately preceding or subsequent to the date of heavy rain, the entry in the table is confined to a single date; if two or more dates are given, the second entry of rainfall represents the accumulated amount for 48 hours, the third the accumulated rainfall for 72 hours, etc. The arrangement of the table is chronologically by months. This arrangement permits us to note that the seasonal variation of excessive rains is not especially well marked; the principal maximum occurs in the months of May, June, July, and August, while there is also a prominent midwinter maximum in February. The minimum falls in September and October, as might be expected.

Accumulated amounts of excessive precipitation at Cincinnati, Ohio, 1871 to June 30, 1913.

Year.	Day.	24 hours.	48 hours.	72 hours.	96 hours.	Year.	Day.	24 hours.	48 hours.	72 hours.	96 hours.
JANUARY.											
1874	6-7	0.72	1.92	......	......	1893	1	1.35	1.37	......	......
1876	18	2.97	......	......	......	1895	5-7	.11	1.64	3.92	......
1876	22-23	.70	1.90	......	......	1897	4-5	.47	1.56	......	......
1876	27-28	1.18	3.53	......	......	1898	9-10	1.57	1.84	......	......
1877	15-16	1.09	1.12	......	......	1898	19-20	.68	2.35	......	......
1880	8	1.16	......	......	......	1898	22-23	1.32	1.55	......	......
1881	31	1.27	......	......	......	1899	13-14	.93	2.00	......	......
1882	4-7	1.05	1.05	1.94	2.52	1906	1-2	.11	1.40	......	......
1885	15	1.46	2.65	2.73	......	1907 [1]	1-3	1.08	2.63	2.71	......
1890	4-7	.28	.34	1.64	2.44	1910	12-14	.19	2.66	2.68	......
1890	15	1.32	......	......	......	1913	5-8	.14	.70	2.22	2.26
1891	31	1.31	......	......	......	1913	10-12	.70	2.48	2.53	......
FEBRUARY.											
1871	17-18	1.50	2.00	......	......	1885	8-9	0.24	1.42	......	......
1873	15-16	.31	1.84	......	......	1887	2-3	1.97	3.31	......	......
1874	6-7	1.04	1.11	......	......	1887	26	1.19	......	......	......
1874	20-23	.43	3.16	3.79	3.82	1893	14-15	1.05	1.43	......	......
1881	7-10	1.00	2.01	2.92	3.01	1894	12	1.14	......	......	......
1882	12-13	.18	1.48	......	......	1897	20-22	.45	1.76	3.21	......
1882	19-21	1.00	2.85	3.31	......	1903	15-16	1.09	1.79	......	......
1883	4-7	1.22	1.24	2.75	3.20	1904	6-7	.03	1.08	......	......
1883	10-11	1.65	1.96	......	......	1908	4-5	.10	1.41	......	......
1883	23-24	1.01	1.10	......	......	1908	13-15	.06	1.90	1.92	1.94
1884	4-7	1.35	2.91	4.56	4.79	1909	23-24	2.69	2.70	......	......
1884	10-13	.14	.73	.79	1.97	1910	26-27	.07	1.97	......	......
1884	19	1.12	......	......	......						

[1] Continuous rain, 11-20; total, 4.37 in.

Accumulated amounts of excessive precipitation at Cincinnati, Ohio, 1871 to June 30, 1913—Continued.

Year.	Day.	24 hours.	48 hours.	72 hours.	96 hours.	Year.	Day.	24 hours.	48 hours.	72 hours.	96 hours.
MARCH.											
1871	2- 3	1.00	1.40			1897	2- 5	0.44	0.75	0.75	5.72
1874	4- 7	.40	.41	1.88	1.93	1897	16-19	1.07	1.10	1.78	1.82
1875	1- 3	1.02	1.05	1.31		1899	28	1.07			
1876	28	1.04				1903	6- 8	.03	1.39	2.49	
1878	12-14	1.82	1.84	1.93		1904	21-22	.23	2.25		
1879	22	1.70				1904	25-26	.75	2.82		
1882	20-21	2.54	2.85			1906	19	1.09			
1883	28-30	.45	.95	2.45		1906	29-30	.66	1.90		
1888	20-21	.13	1.36			1907	12-13	2.00	6.59		
1891	26-27	1.21	1.50			1909	8- 9	.63	1.88		
1896	30	1.08				**1913**	**24-27**	**2.21**	**6.86**	**7.47**	
APRIL.											
1872	8- 9	1.62	1.78			1893	9-11	0.23	1.04	2.38	2.41
1872	15	1.10				1902	28-29	.41	1.69		
1876	13-15	1.90	1.99	2.20		1903	7- 8	.08	1.10		
1880	15-16	.87	2.33			1904	25-27	1.19	1.38	1.52	
1880	24-26	.36	1.80	2.36		1905	20-21	.23	1.25		
1884	22-23	1.02	1.13			1907	23-26	1.15	1.15	2.20	2.51
1887	17-18	.43	2.36			1911	11-14	.31	.42	1.60	1.98
1887	21-23	.06	1.82	2.80		1912	26	1.58			
1890	24-27	.28	.33	1.42	1.49	1913	8-10	.22	1.23	2.14	
1892	18-21	1.72	1.73	2.90	3.18						
MAY.											
1871	30	2.00				1893	1	2.43			
1872	17-18	1.03	2.39			1893	9	1.12			
1875	9-10	1.41	1.57			1893	25-26	2.37	2.38		
1879	25-27	.53	3.31	3.34		1899	29-31	1.12	1.15	1.84	
1880	29-31	1.76	2.23	2.25		1900	9-10	.40	2.07		
1880	9-11	.28	.40	2.42		1902	21-24	2.37	2.37	2.37	4.82
1881	14	1.21				1903	21-22	.08	1.15		
1882	27-28	.46	2.62			1903	27-30	1.13	1.42	1.58	1.96
1883	19-22	.33	.71	2.47	2.52	1904	30-31	1.32	2.40		
1883	26-29	.18	.53	.94	2.06	1905	11-14	3.16	3.35	3.75	5.06
1884	4	1.43				1908	3- 6	.68	1.74	2.43	3.91
1886	11-13	.92	2.16	2.67		1911	30-31	1.14	1.17		
1887	30-31	1.00	1.03			1912	5- 8	1.24	1.65	1.92	2.01
1888	7- 9	.11	1.17	1.25		1912	28-29	.23	1.43		
1889	29-31	.42	1.54	1.62							
JUNE.											
1872	12-14	0.05	1.15	1.63		1881	29	1.00			
1875	21-22	.13	1.13			1886	9	1.68			
1876	1- 3	.30	1.59	1.70		1887	5- 7	1.10	1.79	1.82	
1876	9	1.28				1890	10-13	1.18	1.76	2.26	2.85
1876	23	1.51				1890	14-17	.10	1.65	2.43	2.51
1877	24-26	.06	1.44	1.46		1893	21-22	1.00	2.05		
1878	7-10	.22	.69	2.70	2.83	1896	23-24	1.64	1.69		
1879	8-11	.09	1.55	1.61	1.71	1899	24-25	1.22	1.39		
1879	27-29	2.05	2.61	2.63		1902	27-30	.05	1.80	2.64	2.75
1880	9	1.42				1903	4- 6	.03	1.75	1.88	2.06
1880	13-15	.90	3.52	4.04		1906	25-26	.34	2.52		
1880	25-26	1.96	2.55			1907	21-24	.26	1.30	1.30	1.83
1880	28-29	.50	1.54			1909	8-10	.91	1.05	2.22	
1881	8	1.35									

Accumulated amounts of excessive precipitation at Cincinnati, Ohio, 1871 to June 30, 1913—Continued.

Year.	Day.	24 hours.	48 hours.	72 hours.	96 hours.	Year.	Day.	24 hours.	48 hours.	72 hours.	96 hours.
					JULY.						
1872	15–17	0.14	1.62	2.57	......	1896	23–24	0.07	1.08	......	......
1874	10–11	.17	1.87	......	......	1897	5–6	2.20	2.24	......	......
1875	22–23	1.17	1.27	......	......	1897	24	2.39	......	......	......
1875	27–30	.43	1.63	2.30	2.61	1897	26	1.01	......	......	......
1877	18	1.24	......	......	......	1898	31	1.00	......	......	......
1877	26–27	.24	1.30	......	......	1900	25	1.04	......	......	......
1878	13	1.55	......	......	......	1901	30–31	1.16	1.22	......	......
1880	19	1.54	......	......	......	1902	18	1.39	......	......	......
1881	14	1.54	......	......	......	1903	22	1.18	......	......	......
1889	19	2.40	......	......	......	1906	22–23	2.16	3.45	......	......
1891	7–8	1.46	2.43	......	......	1907	9–11	.16	.99	2.75	......
1891	30	1.59	......	......	......	1910	16–17	1.07	1.98	......	......
1893	26	1.90	......	......	......	1911	6–8	1.43	2.61	3.59	......
1896	9	1.18	......	......	......	1912	17–18	2.52	2.54	......	......
1896	20–21	.06	2.08	......	......						
					AUGUST.						
1871	7–8	1.40	1.45	......	......	1888	20–21	0.26	2.72	......	......
1871	11	2.00	......	......	......	1890	18–21	1.12	1.61	1.68	2.06
1871	24–27	.10	2.40	2.55	2.60	1890	25–27	.05	2.60	2.71	......
1873	11–12	.05	1.40	......	......	1892	11	1.06	......	......	......
1873	25–26	.12	1.41	......	......	1894	10–13	.14	1.34	1.52	1.80
1875	1–3	2.03	2.21	2.22	......	1895	26–27	.81	1.98	......	......
1876	5–8	1.89	2.09	2.34	2.73	1896	1–2	1.89	1.90	......	......
1876	16–18	.10	1.75	2.32	......	1898	18–19	1.18	1.21	......	......
1878	18–21	1.22	1.47	2.07	2.09	1899	5–6	1.51	1.98	......	......
1879	4–7	.06	1.93	2.83	3.94	1899	10–12	.09	1.49	1.55	......
1879	23–25	1.04	2.14	3.81	......	1903	25–27	.14	1.25	1.36	1.38
1880	1–3	.27	.60	2.17	......	1905	19	1.37	......	......	......
1882	23–25	1.17	1.37	1.38	......	1906	17–18	.04	1.34	......	......
1882	26–29	.72	2.60	2.79	2.82	1906	25–27	.08	1.53	1.71	......
1885	6–7	.90	2.62	......	......	1912	8–11	.09	2.02	2.19	2.37
1885	22–25	1.05	1.06	1.07	1.44	1912	19–20	.12	1.51	......	......
1886	15–17	.55	1.72	1.73	......						
					SEPTEMBER.						
1873	22	1.12	......	......	......	1894	15–18	0.12	1.32	1.75	1.82
1874	5	1.14	......	......	......	1896	27–30	.68	1.93	3.67	3.98
1879	1–3	.06	2.05	2.57	......	1898	22	1.24	......	......	......
1879	12–13	1.13	1.28	......	......	1899	7	1.22	......	......	......
1884	23–24	.35	1.66	......	......	1900	6–7	.16	1.24	......	......
1885	8	1.25	......	......	......	1902	1	1.04	......	......	......
1889	2–5	1.50	1.71	1.90	2.14	1903	9–11	.08	1.13	1.24	......
1891	3–6	1.28	1.68	2.13	2.14	1906	26–29	.72	.81	.83	1.96
1892	13–14	2.02	2.10	......	......	1911	5	2.16	......	......	......
1893	11–14	.15	.48	1.58	2.19	1911	8–11	.04	.15	1.49	3.02
1893	30	1.60	......	......	......	1911	14–16	.22	1.23	1.63	......
					OCTOBER.						
1876	22–24	0.76	2.87	2.94	......	1893	3–4	1.42	1.44	......	......
1881	2–4	.36	2.29	2.43	......	1900	6–7	.16	1.24	......	......
1882	13	1.01	......	......	......	1907	3	1.93	......	......	......
1883	1–2	.16	1.72	......	......	1909	10–11	1.24	1.26	......	......
1883	28–29	2.15	3.99	......	......	1910	4–6	.26	2.59	5.41	......

Accumulated amounts of excessive precipitation at Cincinnati, Ohio, 1871 to June 30, 1913—Continued.

Year.	Day.	24 hours.	48 hours.	72 hours.	96. hours.	Year.	Day.	24 hours.	48 hours.	72 hours.	96 hours.
					NOVEMBER.						
1871	13-14	1.40	2.21	......	......	1889	7- 9	0.08	1.10	1.21	......
1873	23-24	1.34	1.69	......	......	1891	10	1.40	......	......	......
1874	16-17	.21	1.29	......	......	1891	22-24	1.39	2.25	2.29	......
1874	22-23	1.82	1.90	......	......	1895	8- 9	.56	1.98	......	......
1875	13-14	1.79	2.29	......	......	1896	27-28	1.38	1.52	......	......
1878	27	1.35	......	......	......	1897	1- 2	1.65	2.73	......	......
1879	14	1.06	......	......	......	1897	25-26	.12	1.27	......	......
1880	4- 6	.72	.73	2.23	......	1898	10-11	1.34	1.92	......	......
1881	17-19	.15	1.37	2.18	......	1899	21-23	.06	1.08	1.09	......
1883	10	1.04	......	......	......	1900	20-23	1.52	1.80	2.07	2.13
1883	21-22	1.81	2.94	......	......	1900	24-26	1.45	1.90	2.35	2.55
1886	22-23	.22	1.42	......	......	1910	27	1.06	......	......	......
1888	8- 9	1.08	2.20	......	......	1911	6- 7	.07	1.08	......	......
					DECEMBER.						
1870	19	1.00	......	......	......	1883	22-24	0.69	3.26	3.71	......
1871	31	2.50	......	......	......	1884	11-12	1.16	1.43	......	......
1873	3- 4	2.47	2.53	......	......	1893	3	1.35	......	......	......
1874	27-29	.06	1.13	1.27	......	1895	25-26	.13	1.52	......	......
1875	24-26	1.68	1.71	2.62	......	1899	11-12	1.16	1.36	......	......
1879	9-10	.16	1.43	......	......	1901	8-10	.03	1.23	1.30	......
1879	22-24	1.24	2.42	3.65	......	1901	14	1.52	......	......	......
1880	4- 5	2.36	3.17	......	......	1902	15-16	1.31	1.53	......	......
1881	14	1.12	......	......	......	1904	24-27	.43	.77	1.97	3.00
1881	20-23	1.18	2.09	2.86	2.94	1905	1- 2	.15	1.38	......	......
1882	5- 6	1.08	1.14	......	......	1910	27-30	.12	.19	1.28	1.29

The statistics of the above table are summarized in the small table below, wherein is shown the maximum rainfall for each month, classified according to the length of the period, whether 24, 48, 72, or 96 hours. From this table we see that the greatest 24-hourly amount in the forty-odd years, 1871–1913, was 3.32 inches in May, 1905; the greatest 48-hourly amount was 6.6 inches in March, 1907; the greatest 72-hourly amount was 7.5 inches in March, 1913; and the greatest 96-hourly amount was 5.7 inches in March, 1897.

Accumulated precipitation in 24, 48, 72, and 96 hours at Cincinnati, Ohio (maximum for each month and for the year).

[In inches.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Max.
In 24 hours	3.0	2.7	2.5	1.9	3.2	2.0	2.5	2.0	2.2	2.2	1.8	2.5	3.2
In 48 hours	3.5	3.3	6.6	2.4	3.3	3.5	3.4	2.7	2.1	4.0	2.9	3.3	6.6
In 72 hours	3.9	4.6	7.5	2.9	3.7	4.0	3.6	3.8	2.6	5.4	2.3	3.6	7.5
In 96 hours	2.5	4.8	5.7	3.2	5.0	2.8	2.6	3.9	4.0	......	2.5	3.0	5.7
Total number of excessive rains	24	25	22	19	29	27	29	33	22	10	26	22	288

The record of 7.5 inches in 72 hours in the March, 1913, rainfall is easily above any other record for a like period, the nearest approach to it being 5.4 inches in October, 1910. The figures in the table also express the principle elsewhere referred to in this paper, viz, that the intensity of precipitation varies inversely as the duration. In 7 out of 12 months the accumulated amounts for 96 hours are less than for a shorter time.

The chronological variation of excessive rains, as determined from the number of excessive rains in each year (not published), seems to follow rather closely the variation in the yearly

amounts of precipitation; thus, there was a maximum number of occurrences of excessive rainfalls in the years 1879–83, inclusive, which period was also one of abundant rains; conversely, years of small rainfall do not yield many occurrences of excessive precipitation, but there does not seem to be any relation between the amount of the excess of the yearly precipitation above normal and the number of occurrences of excessive rains.

The details of the floods in Ohio and Indiana and the course of the wave of water which later passed down river to the Gulf of Mexico are now matters of history and will not be repeated here; it is our purpose, however, to present the statistics of this remarkable flood rather fully and to draw some comparisons with previous floods. Beginning with the precipitation, we present the numerical values of the daily amounts over the Ohio Basin in Table No. 2, below.

In Table No. 2 the stations in Ohio and Kentucky are located in the various watersheds as follows:

Ohio.—Antwerp, Benton Ridge, Toledo, and Wauseon in the Maumee watershed; Fremont, Tiffin, and Upper Sandusky in the Sandusky watershed; Bowling Green, Cleveland, Conneaut, and Hudson in the Lake Erie watershed; Cincinnati, Millport, and Portsmouth along the Ohio; Garrettsville in the Mahoning watershed; Bellefontaine, Dayton, Greenville, and Urbana in the Great Miami watershed; Kings Mills in the Little Miami watershed; Circleville, Columbus, Frankfort, and Marion in the Scioto watershed; and Bangorville, Cambridge, Canal Dover, Canton, Granville, Philo, and Wooster in the Muskingum watershed.

Kentucky.—Falmouth and Scott in the Licking watershed; Pikeville and Catlettsburg in the Big Sandy watershed; Berea, Beattyville, Shelby City, High Bridge, Lexington, and Frankfort in the Kentucky watershed; Edmonton, Franklin, and Calhoun in the Green watershed; Middlesboro, Williamsburg, Burnside, and Hopkinsville in the Cumberland watershed; and Anchorage, Maysville, Louisville, and Marion along the Ohio.

TABLE No. 2.—*Daily amounts of precipitation (in inches and hundredths) at representative stations in the watershed of the Ohio River, Mar. 23–27, 1913.*[1]

	Mar 23.	Mar. 24.	Mar. 25.	Mar. 26.	Mar. 27.	Total.
WESTERN PENNSYLVANIA.						
Regular stations (midnight to midnight):						
Pittsburgh	0.20	0.72	0.55	1.63	0.38	3.51
Erie	1.28	1.38	2.12	0.91	0.58	6.27
Special river stations (7 a. m. to 7 a. m.):						
Beaver Falls	0.00	0.59	1.65	1.79	0.92	4.95
Confluence	0.00	0.00	0.00	1.00	0.76	1.76
Ellwood City	0.00	0.69	1.81	1.61	0.92	5.03
Franklin	0.00	1.41	2.22	1.32	0.88	5.83
Freeport	0.00	0.14	1.53	1.15	0.35	3.17
Greensboro	0.00	0.06	0.04	1.40	1.12	2.62
Lock No. 4	0.00	0.08	0.05	1.50	0.64	2.27
Mosgrove	0.00	0.19	1.77	1.93	0.67	4.56
Parker	0.01	0.62	2.25	1.40	1.25	5.53
Saltsburg	0.00	0.05	0.20	1.50	0.77	2.52
Sharon	0.00	1.19	2.92	1.24	0.84	6.19
Warren	0.00	0.70	1.70	1.36	1.10	4.86
West Newton	0.00	0.10	0.07	1.62	0.64	2.43
Cooperative stations (7 p. m. to 7 p. m.):						
Aleppo	0.10	0.08	0.58	1.09	0.97	2.82
Claysville	0.15	0.17	0.58	1.51	1.02	3.43
Clearfield	0.00	0.64	0.31	1.09	0.90	2.94
Greenville	1.34	1.11	3.74	0.95	0.60	7.74
Indiana	0.23	0.62	0.26	1.17	0.80	3.08
Saegerstown	1.00	1.09	3.70	0.74	0.98	7.51

[1] *Important.*—The daily amounts of precipitation at regular Weather Bureau stations are given from midnight to midnight, seventy-fifth meridian time. At special river stations the amounts include the precipitation which occurred between 7 a. m. of one day and 7 a. m. of the following day, local time, while the amounts at cooperative stations include the precipitation from 7 p. m. of one day to 7 p. m. of the following day, local time.

TABLE No. 2.—*Daily amounts of precipitation (in inches and hundredths) at representative stations in the watershed of the Ohio River, Mar. 23–27, 1913*—Continued.

	Mar. 23.	Mar. 24.	Mar. 25.	Mar. 26.	Mar. 27.	Total.
OHIO.						
Regular stations (midnight to midnight):						
Cincinnati	0.00	2.21	4.15	1.11	0.00	7.47
Cleveland	1.94	1.46	2.66	0.91	0.25	7.22
Columbus	0.53	2.14	2.89	1.40	0.01	6.97
Toledo	1.90	1.82	1.74	0.48	0.25	6.19
Special river stations (7 a. m. to 7 a. m.):						
Kings Mills	0.00	0.69	2.57	4.06	1.22	8.54
Portsmouth	0.00	T.	0.03	2.78	1.40	4.21
Upper Sandusky	0.00	2.00	2.15	3.50	1.19	8.84
Cooperative stations (7 p. m. to 7 p. m.):						
Antwerp	2.45	0.85	2.50	0.12	0.55	6.47
Bangorville	0.90	1.95	5.25	1.55	0.91	10.56
Bellefontaine	1.37	1.52	5.61	2.13	0.53	11.16
Benton Ridge	2.36	2.00	2.64	0.24	0.30	7.54
Bowling Green	2.00	1.50	2.00	0.30	0.25	6.05
Cambridge	0.33	1.09	1.87	2.55	0.88	6.72
Canal Dover	0.62	0.30	2.70	1.35	0.75	5.72
Canton	1.03	2.20	3.00	1.62	0.60	8.45
Circleville	0.15	1.50	1.97	2.29	0.37	6.28
Conneaut	0.90	1.23	2.86	0.97	0.85	6.81
Dayton	0.51	2.91	3.28	1.48	0.76	8.94
Frankfort	T.	1.20	1.67	2.20	1.42	6.49
Fremont	2.50	0.72	2.80	0.20	0.94	7.16
Garrettsville	1.98	1.03	4.61	0.88	0.87	9.37
Granville	0.49	1.43	2.68	2.06	0.50	7.16
Greenville	1.29	1.77	4.45	1.41	0.41	9.33
Hudson	1.60	1.90	4.10	1.15	0.90	9.65
Marion	1.38	1.97	4.39	1.87	1.00	10.61
Millport	0.75	0.90	1.90	1.35	0.70	5.60
Philo	0.36	1.36	1.46	2.29	0.70	6.17
Tiffin	1.98	1.12	3.65	0.47	0.75	7.97
Urbana	0.62	2.13	3.12	2.25	0.54	8.66
Wauseon	2.07	1.14	1.78	0.32	0.34	5.65
Wooster	1.16	1.94	4.84	1.40	0.81	10.65
WEST VIRGINIA.						
Regular stations (midnight to midnight):						
Elkins	0.00	0.00	0.22	0.49	0.70	1.41
Parkersburg	0.08	0.05	0.80	1.84	0.24	3.01
Special river stations (7 a. m. to 7 a. m.):						
Charleston	0.00	0.00	0.00	1.20	1.35	2.55
Creston	0.00	0.00	0.00	1.60	1.47	3.07
Fairmont	0.00	0.03	0.02	1.28	0.92	2.25
Glenville	0.00	0.00	0.00	1.15	1.20	2.35
Hinton	0.00	0.00	0.00	0.62	1.74	2.36
Huntington	0.00	0.00	0.00	2.24	1.90	4.14
Point Pleasant	0.00	0.00	0.20	1.80	1.18	3.18
Rowlesburg	0.00	0.00	0.00	0.90	0.90	1.80
St. Marys	T.	0.19	0.00	1.63	1.00	2.82
Wheeling	0.00	0.18	0.53	1.86	0.50	3.07
Williamson	0.00	0.00	0.00	0.78	1.70	2.48
Cooperative stations (7 p. m. to 7 p. m.):						
Beckley	0.00	0.00	0.00	0.95	1.40	2.35
Bens Run	0.20	0.00	0.52	1.21	0.77	2.70
Cuba	0.00	0.30	0.28	1.48	0.95	3.01
Elkhorn	0.00	0.00	0.97	2.05	0.05	3.07
Grafton	0.00	0.00	0.35	0.80	1.05	2.20
Ryan	0.00	0.00	0.36	1.40	1.29	3.05
Wellsburg	0.23	0.41	0.76	1.83	0.78	4.01

TABLE No. 2.—*Daily amounts of precipitation (in inches and hundredths) at representative stations in the watershed of the Ohio River, Mar. 23–27, 1913*—Continued.

	Mar 23.	Mar. 24.	Mar. 25.	Mar. 26.	Mar. 27.	Total.
KENTUCKY.						
Regular stations (midnight to midnight):						
Lexington	0.00	0.21	1.79	2.46	0.01	4.47
Louisville	T.	0.15	4.95	0.87	T.	5.97
Special river stations (7 a. m. to 7 a. m.):						
Beattyville	0.00	0.00	0.00	3.04	3.28	6.32
Burnside	0.00	0.00	0.00	2.25	3.25	5.50
Catlettsburg	0.00	0.00	0.00	2.36	0.92	3.28
Falmouth	0.00	0.00	0.30	3.23	0.96	4.49
Frankfort	0.00	0.00	0.11	3.35	1.06	4.52
High Bridge	0.00	0.00	0.05	3.02	1.24	4.31
Maysville	0.00	T.	0.16	2.03	1.29	3.48
Paducah	0.00	0.00	1.20	3.64	0.40	5.24
Pikeville	0.00	0.00	0.00	0.80	1.40	2.20
Williamsburg	0.00	0.00	0.00	2.02	2.05	4.07
Cooperative stations (7 p. m. to 7 p. m.):						
Anchorage	0.00	0.20	3.50	1.72	0.08	5.50
Berea	0.00	0.00	1.20	5.25	0.60	7.05
Calhoun	0.00	T.	1.40	2.46	0.13	3.99
Edmonton	0.00	0.00	0.00	4.30	0.09	4.39
Franklin	0.00	0.20	0.00	4.85	T.	5.05
Hopkinsville	0.00	0.20	0.32	2.53	0.10	3.15
Irvington	0.00	0.05	3.75	1.80	0.20	5.81
Marion	0.00	T.	2.28	1.43	T.	3.70
Middlesboro	0.00	0.00	0.00	1.75	1.60	3.35
Scott	T.	2.86	1.50	2.38	0.23	6.97
Shelby City	0.00	0.00	0.61	4.16	0.39	5.16
INDIANA.						
Regular stations (midnight to midnight):						
Evansville	0.29	0.90	4.01	0.30	0.02	5.52
Fort Wayne	2.08	1.98	0.69	0.40	0.21	5.36
Indianapolis	1.27	2.76	1.56	0.34	0.08	6.01
Terre Haute	1.05	2.45	0.77	0.19	0.10	4.56
Special river stations (7 a. m. to 7 a. m.):						
Attica	0.37	2.80	2.28	0.00	0.63	6.08
Bluffton	0.00	3.80	3.00	0.10	0.60	7.50
Elliston	0.00	1.10	6.10	1.20	0.20	8.60
Madison	0.36	2.74	3.67	2.27	T.	9.04
Mount Vernon	0.00	0.21	1.65	2.55	0.37	4.78
Shoals	T.	0.37	6.66	1.80	0.45	9.28
Cooperative stations (7 p. m. to 7 p. m.):						
Anderson	2.34	1.50	2.51	0.50	0.14	6.99
Berne	2.30	2.34	2.56	0.42	0.19	7.81
Butlerville	0.14	2.57	4.43	1.56	0.57	9.27
Collegeville	1.20	1.14	1.86	0.20	0.00	4.40
Connersville	0.68	1.85	5.67	1.46	0.32	9.98
Crawfordsville	2.80	2.30	2.20	0.70	0.00	8.00
Eminence	1.60	1.95	1.45	0.25	0.00	5.25
Farmersburg	0.78	1.92	2.23	0.21	T.	5.14
Greenfield	1.25	2.56	2.32	1.00	0.15	7.28
Huntingburg	2.27	4.50	0.52	0.00	0.00	7.29
Huntington	1.80	1.05	1.95	0.30	0.30	5.40
Judyville	1.97	1.13	1.51	0.27	0.14	5.02
Kokomo	2.18	1.57	1.97	0.00	0.38	6.10
Mauzy	0.56	2.25	5.59	0.98	0.27	9.65
Moores Hill	0.33	1.63	2.78	2.10	0.08	6.92
Princeton	0.05	2.00	4.37	1.05	0.06	7.53
Rome	0.00	0.10	3.13	2.46	0.09	5.78
Salamonia	3.55	1.16	3.04	1.08	0.21	9.04
Salem	0.10	2.00	3.10	1.10	0.20	6.50
South Bend	1.15	0.53	0.88	0.60	0.18	3.34
Underwood	0.01	2.10	3.30	2.30	0.21	7.92

TABLE No. 2.—*Daily amounts of precipitation (in inches and hundredths) at representative stations in the watershed of the Ohio River, Mar. 23–27, 1913*—Continued.

	Mar. 23.	Mar. 24.	Mar. 25.	Mar. 26.	Mar. 27.	Total.
SOUTHERN ILLINOIS.						
Regular stations (midnight to midnight):						
Cairo	0.04	0.02	4.29	0.24	0.02	4.61
Special river stations (7 a. m. to 7 a. m.):						
Shawneetown	0.00	0.52	1.62	2.44	0.74	5.32
Chester	0.00	0.62	2.80	0.22	0.82	4.46
Mount Carmel	T.	0.86	6.20	1.50	0.60	9.16
Cooperative stations (7 p. m. to 7 p. m.):						
Albion	T.	2.10	6.23	0.71	0.07	9.11
Carbondale	0.00	0.25	4.24	0.52	0.07	5.08
Carlyle	T.	1.60	1.92	0.58	T.	4.10
Danville	2.20	1.35	1.40	0.54	0.23	5.72
Equality	T.	0.27	3.02	0.97	T.	4.26
Flora	T.	2.38	3.30	0.40	0.11	6.19
Manteno	1.34	0.29	0.45	0.15	0.07	2.30
Metropolis	0.00	0.35	3.74	1.25	0.05	5.39
Palestine	0.16	1.34	3.67	0.40	0.00	5.57
Tuscola	2.05	1.22	1.23	0.42	0.08	5.00
WESTERN VIRGINIA.						
Regular stations (midnight to midnight):						
Lynchburg	0.00	0.00	0.00	0.27	0.54	0.81
Wytheville	0.00	0.00	0.00	1.70	0.88	2.58
Special river stations (7 a. m. to 7 a. m.):						
Buchanan	0.00	0.00	0.00	0.00	2.20	2.20
Speers Ferry	0.00	0.00	0.00	0.26	2.00	2.26
NORTHERN ALABAMA.						
Special river stations (7 a. m. to 7 a. m.):						
Bridgeport	0.00	0.00	0.00	0.00	1.86	1.86
Florence	0.00	0.00	0.00	0.25	1.44	1.69
Guntersville	0.00	0.00	T.	0.10	0.72	0.82
WESTERN NORTH CAROLINA.						
Regular station (midnight to midnight):						
Asheville	0.00	0.01	0.09	0.69	0.40	1.19
TENNESSEE.						
Regular stations (midnight to midnight):						
Chattanooga	0.00	0.00	0.10	1.58	0.03	1.71
Knoxville	0.00	0.00	0.08	2.18	0.16	2.42
Memphis	0.08	0.00	1.23	0.56	T.	1.87
Nashville	0.00	T.	1.11	1.85	0.01	2.97
Special river stations (7 a. m. to 7 a. m.):						
Carthage	0.00	0.00	0.01	4.50	1.90	6.41
Celina	0.00	0.00	0.00	4.20	2.16	6.36
Clarksville	0.00	T.	0.53	3.47	1.26	5.26
Elizabethton	0.00	0.00	0.00	1.00	1.60	2.60
Johnsonville	0.00	0.10	0.86	4.00	0.64	5.60
Kingston	0.00	0.00	0.00	0.22	2.86	3.08
Newport	0.00	0.00	0.00	T.	1.75	1.75
New River	0.00	0.00	0.00	1.42	2.54	3.96
Cooperative stations (7 p. m. to 7 p. m.):						
Ashwood	0.00	0.00	T.	2.50	0.00	2.50
Benton	0.00	0.00	T.	0.53	0.75	1.28
Byrdstown	0.00	0.00	0.00	0.00	3.70	3.70
Cedar Hill	0.00	0.30	0.20	4.72	0.15	5.37
Dover	0.00	0.24	0.91	2.67	T.	3.82
Erasmus	0.00	T.	0.33	2.07	0.92	3.32
Jackson	0.00	0.00	0.04	2.75	T.	2.79
Kenton	0.00	0.24	0.48	1.79	0.01	2.52
McMinnville	0.00	0.00	0.00	1.25	1.85	3.10
Mountain City	0.00	0.00	0.00	0.63	1.23	1.86
Rogersville	0.00	0.00	0.00	0.33	2.13	2.46
Savannah	0.00	0.48	0.63	5.95	0.04	7.10

A chart of the aggregate rainfall for the period covered by the table is also presented. This chart No. 1 shows by appropriate shading the intensity of the fall in the several parts of the watershed. The figures in red express the total rainfall, in inches and tenths, for the stations and the period covered by Table No. 2. It should be remembered that rain did not begin to fall south of the Ohio River until March 25. High water in the smaller southern tributaries therefore was about a day later than in the northern tributaries.

A careful analysis of the rainfall statistics of the 1913 flood as published in Table No. 2 reveals the important fact that in the beginning rain fell over the headwaters of the streams in Ohio and Indiana sufficient to fill their bank full. Subsequently rain ceased on the headwaters, but continued in the lower reaches of all streams in the States named and extended into the watersheds of the tributaries which enter the Ohio River along the left bank. It is also disclosed that practically all of the flood-producing rain fell over the States of Ohio, Indiana, and Illinois and that the two headwater tributaries of the Ohio, viz, the Allegheny and the Monongahela, were not serious factors in the causation of the flood under discussion.

The rains of the spring of 1912 which caused the greatest flood that the lower Mississippi Valley yet has experienced likewise fell not on the headwaters of the Missouri, the upper Mississippi, the Wabash, nor the Tennessee and the Cumberland, but on the middle and lower portions of the respective basins of those streams, whence the inference that in methods of flood protection by reservoirs or otherwise it will be necessary to care not only for the rain which falls on the headwaters, but also in the low-lying portions of the respective basins.

Table No. 3 follows with river-gage readings made at 8 a. m. eastern time, on the tributaries of the Ohio in Pennsylvania, Ohio, Indiana, Illinois, Kentucky, Tennessee, and West Virginia. The table also contains a column comparing the absolute high water of the March, 1913, flood with records of previous high water. It appears that in general the northern tributaries in Ohio and Indiana were about as much above previous high water as the southern tributaries lacked of reaching previous high-water stages. (See page 27.)

The March, 1913, flood in the Ohio River.—The flood in the main stream was essentially due to the volume of water discharged by the rivers of Ohio and Indiana augmented, of course, by the discharge of the southern tributaries. The watershed of the Allegheny did not receive as much precipitation as did that of the Beaver, immediately to the westward. Practically no rain fell over the Monongahela watershed until the 26th, and while it continued over that watershed until the morning of March 27, the river itself was at no time in flood. At some places the Allegheny exceeded the high stage of the flood of 1865, but the failure of the Monongahela to reach flood stage fortunately prevented a record-breaking rise in the Ohio at Pittsburgh.

At Wheeling, W. Va., 91 miles below Pittsburgh, the volume of the flood was much greater than at Pittsburgh, doubtless due to the great amount of water discharged by the Beaver River. The highest mark at Wheeling fell 2 feet short of the crest of the 1884 flood.

The most important tributary of the Ohio between Wheeling and Parkersburg is the Muskingum, which enters the Ohio at Marietta, 12 miles above Parkersburg. The precipitation over the Muskingum watershed was remarkably heavy. As a result the river crested at Zanesville, Ohio, 70 miles from the mouth of the Muskingum, at 51.8 feet, 15 feet higher than any previously recorded stage. The immense volume of water carried by that river arrived at its junction with the Ohio simultaneously with the flood wave from the Allegheny and the Beaver, thus producing higher stages by as much as 5 feet than in the 1884 flood. One of the first effects of the flood waters near the mouth of the Muskingum was to isolate Parkersburg and Marietta from communication with the outside world by telegraph or telephone; and while some loss resulted from lack of means to transmit warnings, there was still great loss in the district to property which could not be protected.

It is interesting to note the volume of water which flowed past Parkersburg in 24 hours. Fortunately the Weather Bureau is able to present hourly river gage readings made under

FIG. 1.—THE OHIO RIVER IN FLOOD AT CINCINNATI, APRIL 1, 1913.

Steamer Princess over river gage, foot of Broadway, elevated railroad to right; water extends three blocks back.

the supervision of the Parkersburg station from 11 a. m., March 26, to 8 p. m., **March** 31, as in the table below.

Hourly river gage readings, Parkersburg, W. Va., 11 a. m. Mar. 26–8 p. m. Mar. 31, 1913.

	Feet and tenths.		Feet and tenths.		Feet and tenths.
26th, 11 a. m	25.5	28th, 5 a. m	53.9	29th, 11 p. m	58.6
12 m	26.8	6 a. m	54.3	12 md	58.5
1 p. m	28.0	7 a. m	54.5	30th, 1 a. m	58.4
2 p. m	28.7	8 a. m	54.9	2 a. m	58.4
3 p. m	29.9	9 a. m	55.2	3 a. m	58.3
4 p. m	30.5	10 a. m	55.5	4 a. m	58.2
5 p. m	31.8	11 a. m	55.7	5 a. m	58.1
6 p. m	32.5	12 m	56.0	6 a. m	58.0
7 p. m	33.5	1 p. m	56.1	7 a. m	57.9
8 p. m	34.5	2 p. m	56.4	8 a. m	57.9
9 p. m	35.4	3 p. m	56.5	9 a. m	57.8
10 p. m	36.2	4 p. m	56.7	10 a. m	57.6
11 p. m	37.0	5 p. m	56.9	11 a. m	57.6
12 md	37.8	6 p. m	57.1	12 m	57.6
27th, 1 a. m	38.5	7 p. m	57.2	1 p. m	57.5
2 a. m	39.3	8 p. m	57.3	2 p. m	57.4
3 a. m	40.1	9 p. m	57.5	3 p. m	57.2
4 a. m	41.1	10 p. m	57.6	4 p. m	57.0
5 a. m	41.6	11 p. m	57.7	5 p. m	56.9
6 a. m	42.0	12 md	57.8	6 p. m	56.7
7 a. m	42.3	29th, 1 a. m	57.9	7 p. m	56.5
8 a. m	43.0	2 a. m	58.0	8 p. m	56.3
9 a. m	43.8	3 a. m	58.1	9 p. m	56.1
10 a. m	44.6	4 a. m	58.2	10 p. m	55.9
11 a. m	45.1	5 a. m	58.3	11 p. m	55.7
12 m	45.8	6 a. m	58.4	12 md	55.5
1 p. m	46.2	7 a. m	58.5	31st, 1 a. m	55.3
2 p. m	47.0	8 a. m	58.5	2 a. m	55.1
3 p. m	47.7	9 a. m	58.6	3 a. m	54.9
4 p. m	48.1	10 a. m	58.6	4 a. m	54.7
5 p. m	48.8	11 a. m	58.7	5 a. m	54.5
6 p. m	49.2	12 m	58.7	6 a. m	54.3
7 p. m	50.0	1 p. m	58.8	7 a. m	54.1
8 p. m	50.3	2 p. m	58.8	8 a. m	53.8
9 p. m	50.7	3 p. m	58.8	11 a. m	53.0
10 p. m	51.3	4 p. m	58.8	1 p. m	52.5
11 p. m	51.8	5 p. m	58.8	3 p. m	52.0
12 md	52.3	6 p. m	58.9	4 p. m	51.8
28th, 1 a. m	52.8	7 p. m	58.9	5 p. m	51.5
2 a. m	53.2	8 p. m	58.9	6 p. m	51.2
3 a. m	53.4	9 p. m	58.8	7 p. m	50.9
4 a. m	53.7	10 p. m	58.7	8 p. m	50.6

In order to form an idea of the approximate run-off during the storm period we have computed the discharge of the Ohio at Parkersburg, W. Va., for the seven days, March 26–April 1, when the river was above a stage of 35 feet. The rain period in the watershed above Parkersburg was March 24–27. The increased flow in the river became noticeable on March 26, when the mean stage, 8 p. m. to 8 p. m., was 22.1 feet. A stage of 35 feet was reached and passed at 8 p. m. of the 26th. The total discharge for the seven days when the river was above that stage was approximately 323,654,400,000 cubic feet; deducting from this amount that which may be called the normal flow at the time the rains began, and assuming that the normal flow was constant for the seven days, we have 323,654,400,000—27,216,000,000=296,438,400,000 cubic feet as the excess discharge due to the rains.

The rainfall for the watershed of the Ohio above Parkersburg averaged 4.7 inches; in some parts of the watershed the actual rainfall was as much as 10 inches, while in other parts it was less than 2 inches. The computed rainfall on the basis of an average of 4.7 inches per square mile is 406,188,200,000 cubic feet, or about 2.8 cubic miles of water. The approximate run-off as determined above was 296,438,400,000 cubic feet, or about 2 cubic miles of water, and the percentage of excess run-off to total rainfall for the seven days was 73, an extremely high value of run-off, but not an improbable one, considering the time of year and the probable height of ground water at the beginning of the period. The above figures of excess discharge for the seven days correspond to a discharge of 13 second-feet per square mile of watershed. The maximum discharge was, however, 17.5 second-feet per square mile.

From Parkersburg to Cincinnati the river rose very irregularly. At the latter place it rose nearly a foot an hour during the night of the 25th–26th and reached 50 feet, the flood stage, by 7 a. m. of the 26th. By that hour the river stood 21.5 feet higher at Cincinnati than at Maysville, Ky., the last named being 60 miles upriver.

The explanation of this extraordinary 24-hour rise at Cincinnati was furnished by Mr. W. C. Devereaux of the Cincinnati office, viz, that it was due to the volume and strength of the

current issuing from the Great Miami River where it joins the Ohio, about 15 miles below Cincinnati, thus causing the Ohio to back up in that stretch of the stream between the mouth of the Great Miami and Cincinnati. A river packet encountered the output of the Great Miami on the night of March 25–26, and so great was the force of the current that the captain of the packet was obliged to steer almost directly into the current to prevent being carried onto the opposite bank of the river.[1]

The flood discharge of the Scioto came out 24 hours later than that of the Great Miami, as did also that of the Muskingum and other small rivers; thus there was not perfect synchronism in the flood discharge of the Ohio and Indiana streams. To this lack of synchronism may be ascribed the immunity from higher stages than were actually recorded from Cincinnati to Cairo. At the time the river reached flood stage at Cincinnati the principal flood wave was about 24 hours upriver from Parkersburg. The latter place is 286 miles upstream from Cincinnati, or about three days run for a normal flood wave. As a matter of fact, the crest of the rise at Cincinnati was not reached until six days after the river attained a flood stage. Meantime much of the flood water first discharged into the river had passed downstream. The Cincinnati crest, 70 feet, was reached at 5 a. m. of April 1, and that height was maintained until midnight of that date, when the river began to fall slowly. As a result of the lack of synchronism in one; however, the highest water on record was reached at all points from Parkersburg to the discharge of flood waters into the trunk stream, the flood wave in the latter was a very flat Maysville (see diagram 1).

The flood, Cincinnati to Louisville.—At Madison, Ind., 86 miles below Cincinnati, the crest of the flood wave, 62.8 feet, was reached on April 1, 1913. That stage exceeds the record of the 1884 flood by 1 foot and is the only instance where the 1913 flood exceeded the earlier flood between Cincinnati and Louisville. At Louisville the crest stage of 44.9 feet on April 2, 1913, fell short of previous high record by 1.8 feet. For a detailed account of the flood at Louisville see accompanying papers, page 81.

The flood, Louisville to Cairo.—The river between Louisville and Cairo was about 9 feet below flood stage when the rains of March 25–27 set in. As at Cincinnati it rose rather rapidly during the 48 hours immediately following the rains, but the bulk of the flood water from the Wabash, on the north, did not come in until the night of March 29–30. One effect of the Wabash flood was to back up the Ohio, thus causing relatively high-crest stages at Mount Vernon, Ind., Henderson, Ky., and Evansville, Ind. The crest at Evansville, 48.3 feet, occurred about noon of April 5, and is believed to have been due to a short period of heavy rains over the lower Ohio and Green River Valleys, combined with the local ponding effect of the Wabash.

At Cairo, Ill., the initial stage on March 25, was 40.9 feet, 4.1 feet below flood stage. Flood stage was reached on March 27, and a crest stage of 54.8 feet on April 4. This stage is 0.8 foot higher than ever before recorded. The river stood at this unprecedented stage until April 9, and then began to fall very slowly. The stages of the river at Cairo are, of course, conditioned on the levees withstanding the water, and since those protecting Cairo have been raised and strengthened in recent years, we should expect higher stages at Cairo than have hitherto been recorded. Fortunately, the Mississippi was not at a flood stage at the mouth of the Ohio, and thus the Cairo stage was not so high as it might have been had the conditions of the 1912 flood prevailed. Nevertheless the river passed slowly above the hitherto record stage of 54 feet reached on April 6, 1912, and on April 4, 1913, touched the mark of 54.8 feet—higher by 0.8 foot than ever before recorded. It hung at the 54.8-foot mark for a period of about 72 hours; meanwhile the people who had remained at Cairo, assisted by the State militia, were making heroic efforts to save the levees and the city from total destruction. On April 7, 1913, the river began to fall, almost imperceptibly at first, but more rapidly by the 18th, and on the 22d of the month it passed below the flood stage, thus ending the most memorable flood that has yet menaced the lower Ohio River.

[1] The effect of the Great Miami water was noticeable as far up river as Ripley, Ohio.

FIG. 2.—WABASH IN FLOOD AT MOUNT CARMEL, ILL.

FIG. 3.—RIVER FRONT, PADUCAH, KY., APRIL, 1913.

TABLE No. 3. —*Daily river gage readings (in feet and tenths) Mar. 22–29, 1913, and crest stages as compared with previous highest water at special river stations in the watershed of the Ohio.*

	Flood stage (feet).	Previous highest stage. Height.	Previous highest stage. Date.	March, 1913. 22	23	24	25	26	27	28	29	1913 Highest.	1913 Date.	Compared with previous highest.
LAKE ERIE SYSTEM.														
Sandusky River:														
Tiffin, Ohio	7	18.5	Apr. 2, 1904	2.4	2.4	7.0	12.5	19.4†	16.0†	12.0†	8.0†	19.4	Mar. 26	+ 0.9
Fremont, Ohio	10	16.5	—— —, 1904	......	......	9.4	13.5	21.5	21.5	14.3	11.0	21.5	...do.....	+ 5.0
Maumee River:														
Fort Wayne, Ind	15	22.5	Mar. 8, 1908	7.0	6.7	19.6	[a]24.0	26.0	26.0	25.1	23.7	26.1	...do.....	+ 3.6
Napoleon, Ohio	13	18.8	Mar. 2, 1910	1.0	0.8	9.2	16.0	22.0	25.0	22.5	18.0	25.0	Mar. 27	+ 6.2
OHIO RIVER SYSTEM.														
Clarion River:														
Clarion, Pa	10	16.0	Mar. 20, 1905	2.7	2.4	3.2	13.5	12.0	12.3	10.2	7.2	13.9	Mar. 25	− 2.1
Conemaugh-Kiskiminetas:														
Johnstown, Pa	7	21.0	May 31, 1889	2.8	2.6	2.5	2.5	3.0	5.5	4.6	4.0	5.5	Mar. 27	−15.5
Saltsburg, Pa	6	22.1	—— —, 1859	1.3	1.2	1.0	1.0	1.6	6.2	6.3	4.2	7.7	...do.....	−14.4
Allegheny River:														
Olean, N. Y	12	19.3	June 1, 1889	2.2	2.0	2.7	6.6	14.0	14.4	15.2	12.6	15.6	...do.....	+ 3.7
Warren, Pa	14	17.4	Mar. —, 1865	2.4	2.2	3.8	8.0	14.1	14.8	14.1	12.5	15.2	...do.....	− 2.2
Franklin, Pa	15	15.4	Apr. 30, 1909	3.5	3.2	6.1	11.6	22.0	21.1	19.5	15.3	22.5	Mar. 26	+ 7.1
Parker, Pa	20	28.0	Mar. —, 1865	3.8	3.2	5.0	15.4	24.5	24.5	23.0	17.0	25.7	...do.....	− 2.3
Freeport, Pa	20	32.7	Feb. 18, 1891	6.5	6.2	5.9	16.2	26.4	31.9	29.5	23.5	32.2	Mar. 27	− 0.5
Springdale, Pa	27	33.0	Mar. 16, 1908	11.9	11.4	11.2	19.0	30.0	36.5	34.3	28.3	36.5	...do.....	+ 3.5
Cheat River:														
Rowlesburg, W. Va	14	22.0	July 10, 1888	3.3	3.3	3.2	3.2	3.1	5.5	7.7	5.5	7.7	Mar. 28	−14.3
Youghiogheny River:														
Confluence, Pa	10	18.6	Mar. 14, 1907	1.6	1.3	1.3	1.1	1.6	4.9	4.8	3.5	5.6	Mar. 27	−13.0
West Newton, Pa	23	30.6	Feb. 27, 1912	2.0	1.8	1.5	1.3	2.2	7.4	8.5	5.7	9.7	...do.....	−20.9
Monongahela River:														
Fairmont, W. Va	25	37.0	July 10, 1888	15.1	15.0	14.9	14.8	14.8	20.2	22.4	19.1	23.6	...do.....	−13.4
Greensboro, Pa	18	39.0	.....do.......	8.0	7.9	7.8	7.7	8.0	14.6	18.7	13.6	18.7	Mar. 28	−20.3
Lock No. 4, Pa	28	42.0	July 11, 1888	8.8	8.5	8.2	9.0	10.0	16.2	25.2	20.2	25.2	...do.....	−16.8
Mahoning River:														
Youngstown, Ohio	5	15.8	Jan. 21, 1904	0.6	0.5	4.7	15.5	[1]22.9	......	......	10.4	[2]22.9	Mar. 26	+ 7.1
Beaver River:														
Beaver Falls, Pa	11	15.4	Jan. 22, 1904	4.6	4.4	6.6	13.2	16.7	17.4	15.1	12.0	17.4	Mar. 27	+ 2.0
Tuscarawas River:														
Canal Dover, Ohio	8	12.0	....	......	......	2.3	7.0	13.0	15.0	16.1	9.0	16.1	Mar. 28	+ 4.1
Muskingum River:														
Coshocton, Ohio	8	22.0	Mar. 24, 1898	1.0	1.2	2.5	11.0	......	......	......	......	[3]20.0	Mar. 25	− 2.0
Zanesville, Ohio	25	36.8	.....do.......	9.9	9.7	9.9	21.2	......	51.8	......	......	51.8	Mar. 27	+15.0
Beverly, Ohio	25	35.0	Mar. —, 1898	7.9	7.6	7.7	16.6	......	46.5	......	......	46.5	...do.....	+11.5
Little Kanawha River:														
Glenville, W. Va	20	21.2	Jan. 9, 1907	1.6	1.4	1.4	1.6	2.0	15.2	11.0	3.2	20.0	...do.....	− 1.2
Creston, W. Va	20	25.8	Apr. 20, 1901	3.1	3.1	2.9	2.8	4.2	16.0	18.9	9.5	20.4	Mar. 28	− 5.4
New-Great Kanawha River:														
Radford, Va	14	34.0	Sept. 15, 1878	1.4	1.2	1.1	1.0	1.0	7.3	9.8	4.2	11.5	Mar. 27	−22.5
Hinton, W. Va	14	23.0	Sept. 13, 1878	3.2	3.1	3.0	2.9	2.8	6.5	11.6	7.2	14.5	Mar. 28	− 8.5
Charleston, W. Va	30	46.9	Sept. 29, 1861	6.0	5.9	5.7	5.5	5.5	10.2	33.0	30.0	34.8	...do.....	−12.1
Big Sandy River:														
Williamson, W. Va	26	24.5	June 14, 1907	3.7	3.4	3.2	3.1	3.2	26.4	18.0	8.9	30.4	Mar. 27	+ 5.9
Pikeville, Ky	40	39.5	Aug. —, 1903	5.1	5.0	4.9	4.8	4.5	34.0	21.5	10.4	39.0	...do.....	− 0.5
Scioto River:														
Columbus, Ohio	17	21.3	Mar. 23, 1898	4.4	4.8	6.2	21.9	20.9	19.7	17.4	14.7	22.9	Mar. 25	+ 1.6
Circleville, Ohio	12	19.3	July 17, 1884	......	......	......	11.6	24.2	20.3	16.2	13.8	24.2	Mar. 26	+ 4.9
Chillicothe, Ohio	14	28.3	Mar. 24, 1898	1.6	1.6	1.6	11.9	......	......	......	24.6	37.8	...do.....	+ 9.5
Licking River:														
Falmouth, Ky	25	38.0	—— —, 1854	3.9	4.2	4.0	3.6	29.1	33.8	32.2	23.6	34.1	Mar. 27	− 3.9
Miami River:														
Dayton, Ohio	18	21.3	—— —, 1866	3.0	3.0	7.0	[4]24.0	[5]28.1	[5]22.2	[5]15.7	11.6	29.0	Mar. 25	+ 7.7
Hamilton, Ohio	12	21.2	Mar. 24, 1898	3.0	3.0	4.8	19.6	......	25.0	19.2	14.8	34.6	Mar. 26	+13.4

† Estimated.

[a] Dyke broke on 25th and flood waters passed around the gage; subsequent readings not comparable with preceding ones.

[1] About 22.9.

[2] No record after the 26th.

[3] Obtained by survey.

[4] Approximated.

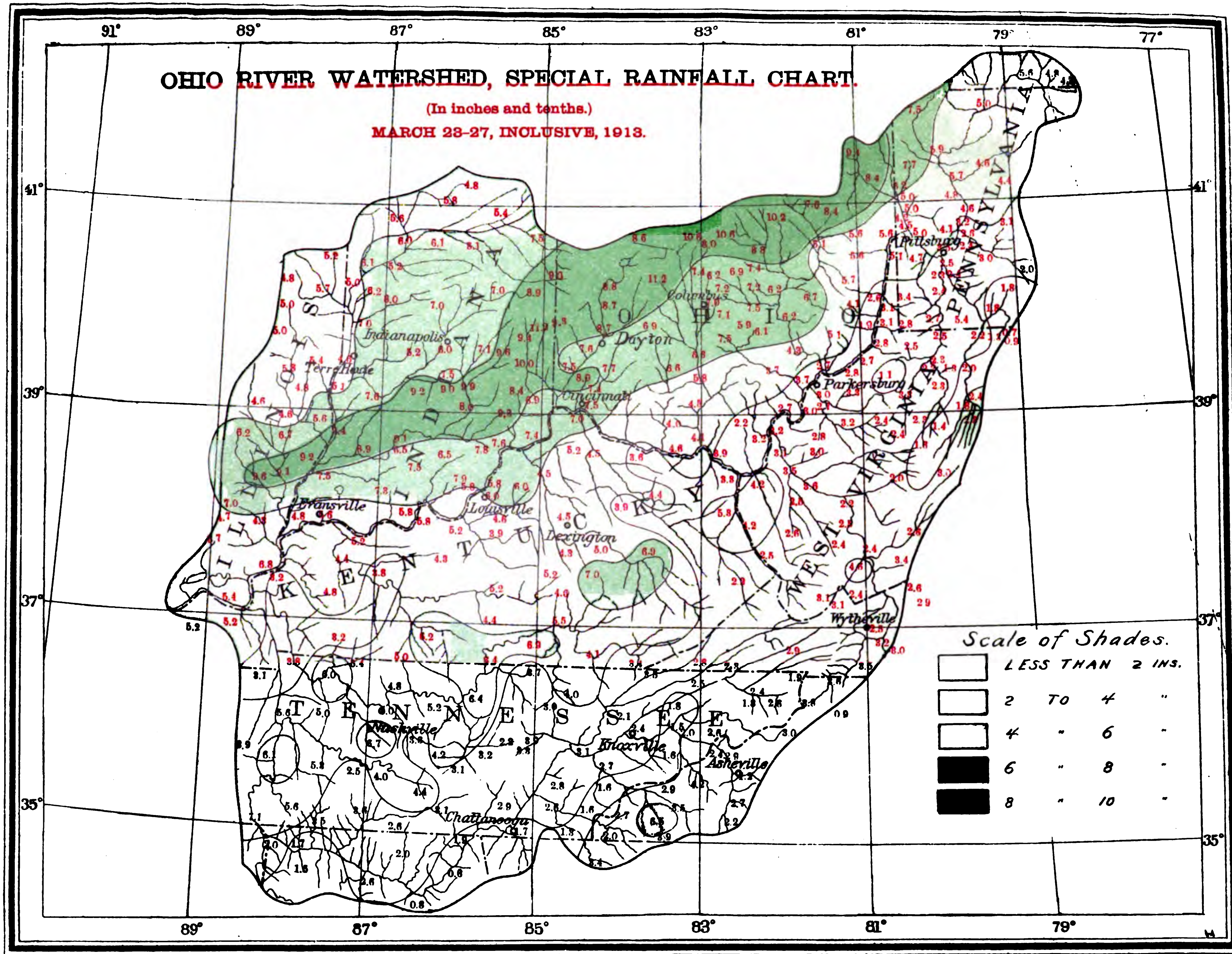
[5] Measurements made at Viaduct Bridge.

TABLE No. 3.—*Daily river gage readings (in feet and tenths) Mar. 22–29, 1913, and crest stages as compared with previous highest water at special river stations in the watershed of the Ohio*—Continued.

	Flood stage (feet).	Previous highest stage.		March, 1913.								1913		Compared with previous highest
		Height.	Date.	22	23	24	25	26	27	28	29	Highest.	Date.	
Little Miami River:														
Kings Mills, Ohio	17	....	....	....	....	3.3	17.8	33.7	....	....	....	33.7	Mar. 26	....
Kentucky River:														
Beattyville, Ky	30	37.5	Mar. 1, 1903	0.9	0.8	1.6	2.0	11.6	37.0	38.6	19.5	39.9	Mar. 28	+ 2.4
High Bridge, Ky	17	30.0	Jan. 30, 1902	11.5	11.4	11.3	11.1	21.0	34.6	33.4	33.5	34.6	Mar. 27	+ 4.6
Frankfort, Ky	31	44.0	Feb. —, 1878	8.6	8.7	8.5	8.5	15.8	35.2	38.3	37.5	38.3	Mar. 28	− 5.7
White River:														
Anderson, Ind	9	18.8	Mar. 23, 1904	4.3	3.8	11.8	17.6	20.6	14.0	10.2	7.8	22.1	Mar. 25	+ 3.3
Indianapolis, Ind	12	19.5	Apr. 1, 1904	4.7	....	11.0	18.0	....	....	....	....	25.7	Mar. 26	+ 6.2
Elliston, Ind	21	29.6	Mar. 5, 1897	....	....	11.8	23.8	27.8	31.3	30.4	28.6	31.3	Mar. 27	+ 1.7
Shoals, Ind	20	34.1	Mar. 30, 1904	7.4	8.0	8.8	21.6	29.5	37.0	42.2	41.7	42.2	Mar. 28	+ 8.1
New River:														
New River, Tenn	25	33.0	Feb. —, 1903	3.2	2.9	2.6	2.4	4.1	23.5	5.6	3.9	23.5	Mar. 27	− 9.5
Wabash River:														
Bluffton, Ind	12	16.7	Apr. —, 1904	3.2	2.5	12.3	17.5	20.0	19.0	13.8	12.3	20.0	Mar. 26	+ 3.3
Logansport, Ind	12	17.3	Feb. —, 1883	3.6	3.8	12.1	....	22.5†	....	....	....	22.5	...do.....	+ 5.2
Attica, Ind	12	29.7	Aug. 3, 1875	6.2	6.8	15.9	24.6	31.6	33.4	31.6	28.5	33.4	Mar. 27	+ 3.7
Terre Haute, Ind	16	27.7	Feb. 18, 1883	7.1	7.0	14.5	19.5	27.0	31.2	30.8	29.2	31.3	...do.....	+ 3.6
Mount Carmel, Ill	15	28.3	Aug. 7, 1885	11.9	13.4	13.6	18.3	21.4	23.0	24.8	27.8	31.0	Mar. 30	+ 2.7
Cumberland River:														
Burnside, Ky	50	65.0	Mar. 30, 1902	8.7	10.5	9.1	8.2	15.2	57.2	58.0	40.0	61.5	Mar. 28	− 3.5
Carthage, Tenn	40	54.3	Apr. 7, 1886	15.8	16.4	15.7	15.5	21.0	37.5	43.9	47.0	47.0	Mar. 29	− 7.3
Nashville, Tenn	40	55.3	Jan. 22, 1882	21.5	17.4	17.5	16.2	25.0	39.3	42.7	42.8	44.9	Apr. 2	−10.4
Clarksville, Tenn	46	60.6	Jan. —, 1882	29.7	24.4	20.6	20.1	31.6	47.3	50.5	50.5	50.9	Mar. 28	− 9.7
Clinch River:														
Speers Ferry, Va	20	26.6	Feb. 28, 1902	2.6	2.4	2.0	1.6	1.0	12.0	17.5	7.2	18.2	Mar. 27	− 8.4
Clinton, Tenn	25	45.0	Mar. 31, 1886	9.4	8.7	8.2	7.8	7.6	23.4	26.5	29.9	30.2	Mar. 29	−14.8
Holston River:														
Rogersville, Tenn	14	17.5	Jan. 23, 1906	4.0	3.9	3.6	3.4	3.3	7.4	19.1	8.5	19.1	Mar. 28	+ 1.6
French Broad River:														
Dandridge, Tenn	12	28.0	May 21, 1901	4.9	3.5	3.1	3.0	2.9	8.5	12.2	8.4	16.0	...do.....	−12.0
Hiwassee River:														
Charleston, Tenn	22	32.2	Mar. 31, 1886	10.0	6.4	5.2	4.8	5.2	13.2	20.0	14.5	20.3	...do.....	−11.9
Little Tennessee River:														
McGhee, Tenn	20	39.0	Mar. —, 1867	8.8	6.8	6.2	5.9	5.9	13.8	17.5	11.2	21.6	Mar. 27	−17.4
Tennessee River:														
Knoxville, Tenn	12	39.0	Mar. —, 1875	4.5	4.8	4.2	3.5	3.2	7.3	20.9	20.1	21.6	Mar. 28	−17.4
Chattanooga, Tenn	33	58.6	Mar. 11, 1867	12.9	12.9	12.3	11.2	10.1	13.3	25.4	31.2	33.3	Mar. 30	−25.3
Bridgeport, Ala	24	41.0	——— —, 1867	11.2	7.0	10.4	9.4	8.5	9.2	16.4	20.6	23.7	Mar. 31	−17.3
Florence, Ala	16	32.5	Mar. 19, 1897	18.0	16.0	13.7	12.0	10.7	13.7	14.0	15.7	18.5	Mar. 21	−14.0
Johnsonville, Tenn	31	48.0	Mar. 24, 1897	27.5	28.0	28.5	28.4	29.4	32.1	33.0	33.3	33.3	Mar. 29	−14.7
Ohio River:														
Pittsburgh, Pa	22	35.5	Mar. 15, 1907	5.3	4.8	4.5	7.8	20.1	28.1	30.4	24.8	30.4	Mar. 28	− 5.1
Wheeling, W. Va	36	53.1	Feb. 7, 1884	8.8	8.3	7.5	11.5	30.5	45.5	50.8	50.0	51.1	...do.....	− 2.0
Parkersburg, W. Va	36	53.9	Feb. 9, 1884	10.5	10.0	9.5	10.0	22.1	43.0	54.9	58.7	58.9	Mar. 29	+ 5.0
Point Pleasant, W. Va	39	60.0	Feb. —, 1884	14.1	12.3	11.1	10.1	13.2	34.1	50.6	60.2	62.8	Mar. 30	+ 2.8
Huntington, W. Va	50	65.6	Feb. 9, 1884	19.7	17.9	16.1	14.1	17.2	39.4	54.5	63.8	66.4	...do.....	+ 0.8
Catlettsburg, Ky	50	66.2	Feb. 12, 1884	19.5	17.3	13.8	15.5	17.2	41.1	56.8	65.1	67.7	Mar. 31	+ 1.5
Portsmouth, Ohio	50	66.3	.....do.......	21.5	19.1	17.4	16.1	21.9	51.0	61.9	62.8	67.9	...do.....	+ 1.3
Maysville, Ky	50	65.7	Feb. 14, 1884	23.1	20.3	18.4	17.1	28.8	44.3	57.5	62.8	66.4	...do.....	+ 0.7
Cincinnati, Ohio	50	71.1	.....do.......	27.5	24.7	22.6	29.3	50.3	57.2	62.6	66.0	70.0	Apr. 1	− 1.1
Madison, Ind	46	61.8	Feb. 15, 1884	25.1	23.6	21.6	27.5	43.5	53.6	57.0	59.6	62.8	...do.....	+ 1.0
Louisville, Ky	28	46.7	.....do.......	11.3	10.8	10.0	11.4	22.5	33.6	38.4	41.1	44.9	Apr. 2	− 1.8
Evansville, Ind	35	48.0	Feb. 19, 1884	28.4	28.3	27.5	26.0	30.1	36.6	40.4	43.0	48.4	Apr. 5	+ 0.4
Shawneetown, Ill	35	56.4	Feb. 24, 1884	29.3	29.6	29.3	28.9	31.1	34.9	38.3	41.9	59.5	...do.....	+ 3.1
Paducah, Ky	43	54.2	Feb. 23, 1884	33.6	34.3	34.4	34.3	36.9	38.5	40.7	42.6	54.3	Apr. 7	+ 0.1
Cairo, Ill	45	54.0	Apr. 6, 1912	39.0	39.9	40.3	40.9	43.5	45.5	47.4	49.1	54.8	Apr. 4, 7	+ 0.8

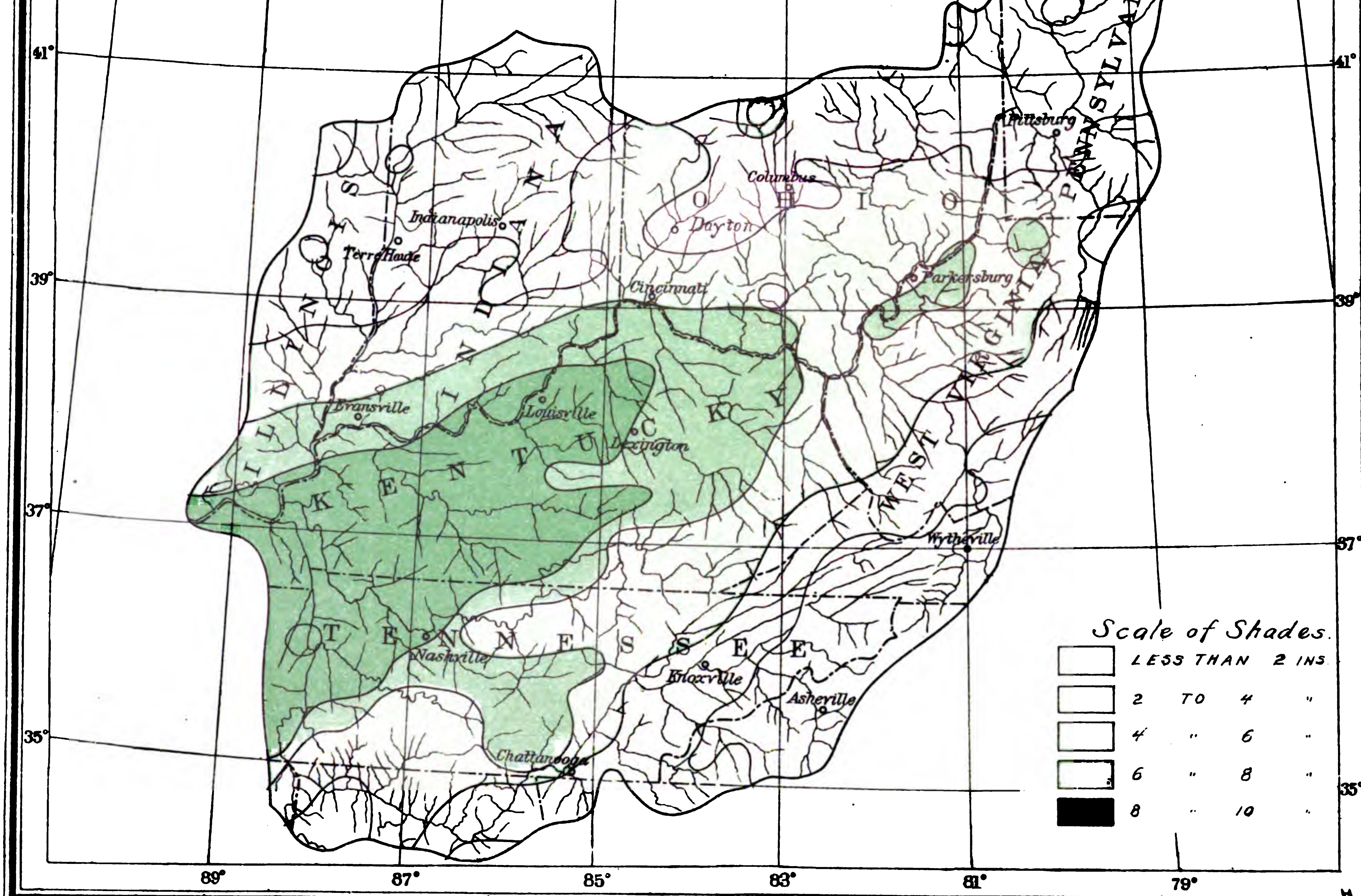
† Determined by survey.

Chart 1, Part 2.



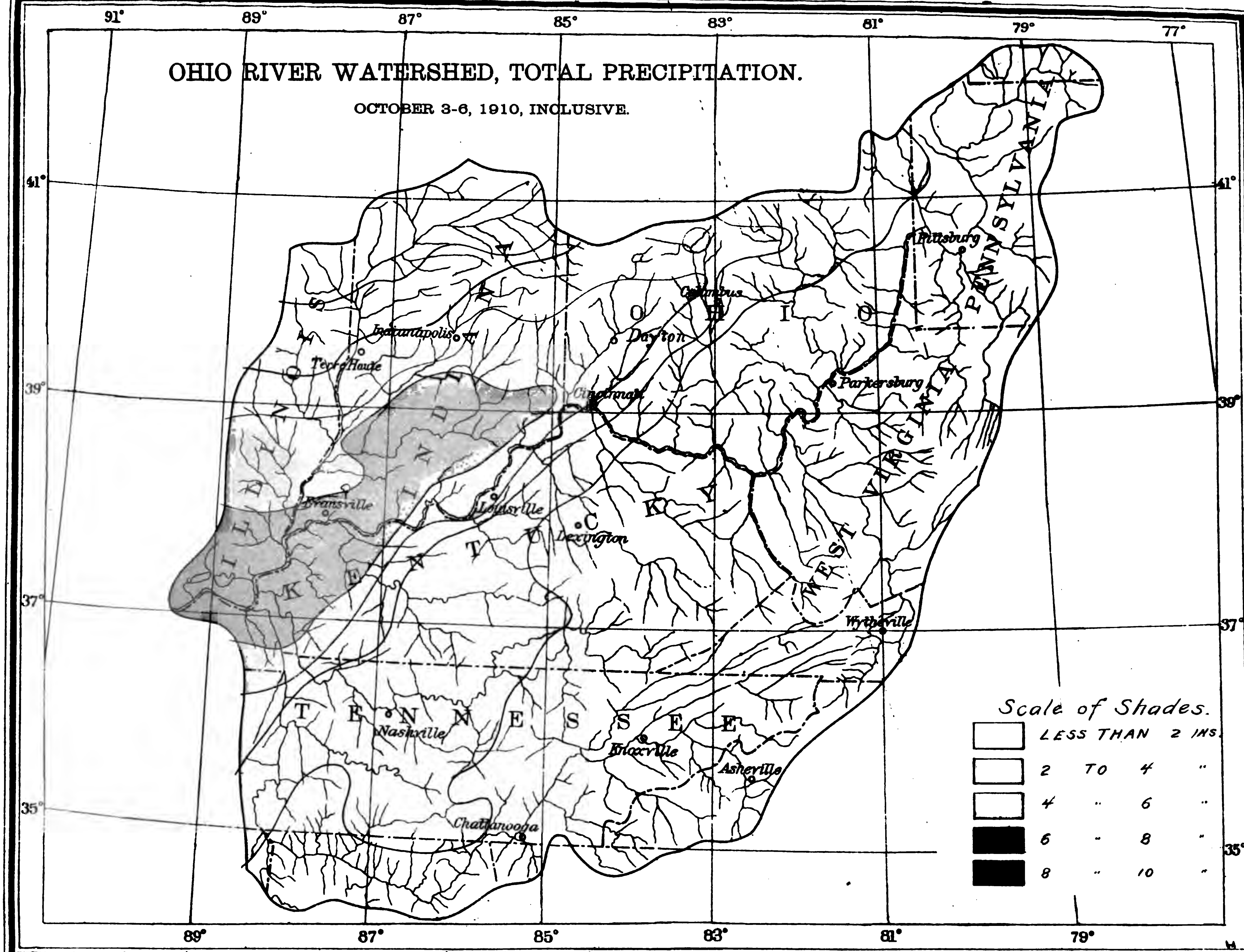
OHIO RIVER WATERSHED, TOTAL PRECIPITATION.

JANUARY 1-13, 1913, INCLUSIVE.



OHIO RIVER WATERSHED, TOTAL PRECIPITATION.

OCTOBER 3-6, 1910, INCLUSIVE.



OHIO RIVER WATERSHED, TOTAL PRECIPITATION.

FEBRUARY 4-7, 1884, INCLUSIVE.

THE FLOOD IN THE OHIO RIVER AS COMPARED WITH PREVIOUS FLOODS.

Fragmentary records of previous floods in the Ohio River at Pittsburgh go back to 1806, but probably the best authenticated record of an early flood is that of February 10, 1832, when a stage of 35 feet, on the Pittsburgh gage, or 13 feet above the present flood stage, was reached. This high record, moreover, stood as such for three-quarters of a century, or until March 15, 1907, when a stage of 35.5 feet was reached, half a foot higher than the 1832 record. The flood at Pittsburgh during March, 1913, came mostly from the Allegheny River, and was not so great by about a foot as the January flood of the present year. (See Table No. 1.)

The greatest of floods in the Ohio River between Pittsburgh and Cairo during the forty-odd years that the Weather Bureau has been making daily observations of stages of the river, whether the order of magnitude of the flood be determined by the crest stage reached or the volume of water carried, was undoubtedly that of February 6–23, 1884, although March, 1913, was a close second, and indeed in several stretches of the river as before stated the crest stages of the March–April, 1913, flood overtopped those of the earlier flood. From St. Marys, W. Va., to probably a short distance below Maysville, Ky., the stages of the March, 1913, flood were the highest ever known; at Parkersburg the previous high record of 1884 was exceeded by 5 feet. The Muskingum River of Ohio empties into the main stream at Marietta, Ohio, about 12 miles upriver from Parkersburg. This river, at Zanesville, Ohio, 70 miles from its mouth, attained a stage 15 feet above previously known high water. The result of suddenly discharging an amount of water into a stream greatly in excess of the stream's capacity to carry it off must be a local ponding in the vicinity of the discharge of the lesser into the greater stream. The simultaneous arrival of the headwaters flood wave and the Muskingum's output doubtless explains the extraordinarily high stages at Marietta and Parkersburg.

Below Parkersburg the excess of the 1913 flood over that of 1884 gradually decreased, due to the fact that the northern tributaries had run out and there were practically no floods in the southern tributaries; giving the Ohio flood waters a chance to back up the valleys and spread over a large area of country. This was especially noticeable at Point Pleasant, where the water spread over the lower portion of the Great Kanawha Valley and the excess in height decreased to 2 feet, and again below Maysville, where the Ohio Valley widens out and the excess entirely disappears.

In 1884 the flood in the Ohio at Cincinnati must have been augmented by flood waters in the tributaries which enter the river near that city to produce the stage it did.

In 1913 the flood was augmented below Louisville by additional water from the Wabash, due to heavy opportune rains in that valley; below the mouth of the Green River the 1913 flood exceeded that of 1884.

The small table below presents comparative statistics of the floods of February, 1884, and March, 1913, respectively, and we also present a diagram which graphically shows the crest stages of the floods along the Ohio River from Pittsburgh to Cairo (Diagram No. I). The crest stages are plotted in terms of excess in feet above the flood stage for each point at which daily gage readings were made.

Comparative stages, Ohio River, in floods of February, 1884, and March, 1913, respectively.

[Plus sign indicates a higher stage in 1913 than in 1884, and minus sign the contrary.]

Stations.	Crest stage.		Difference.	Stations.	Crest stage.		Difference.
	1884	1913			1884	1913	
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
Pittsburgh, Pa	33.3	30.4	−2.9	Cincinnati, Ohio	71.1	70.0	−1.1
Wheeling, W. Va	52.4	51.1	−1.3	Louisville, Ky	46.6	44.8	−1.8
Parkersburg, W. Va	53.9	58.9	+5.0	Evansville, Ind	48.0	48.4	+0.4
Point Pleasant, W. Va	60.8	62.8	+2.0	Paducah, Ky	54.2	54.3	+0.1
Portsmouth, Ohio	66.2	67.9	+1.7	Cairo, Ill	51.8	54.8	+3.0

Further comparisons of 1884 and 1913 floods.—The antecedent conditions of the two floods were quite unlike; the 1913 flood was the result of torrential rains crowded into a very short space of time when the conditions were excellent for a large surface run-off, and it came later in the year when the soil was free of frost. The 1884 flood was the result of only moderately heavy rains (see Chart No. 4 and Table 4) coming on the crest of a midwinter thaw. In fact there were two distinct thaws in a period of mild and rainy weather that continued from February 4 to February 14. The first and most pronounced thaw culminated on February 5, with average temperatures of about 60° F., in the early morning throughout the watershed.

The period of moderately heavy rains was approximately coincident with the culmination of the thaw just mentioned, viz, February 5, 6, and 7. The greatest daily fall was but 0.93 inch for the entire watershed as determined from the reports which appear in Table No. 4. A second maximum of rainfall occurred on the 13th at a time when the flood crest was about at Cincinnati. The unusually high stage recorded at that place may have been due to the effect of this second maximum of precipitation occurring when the river was already at a high stage.

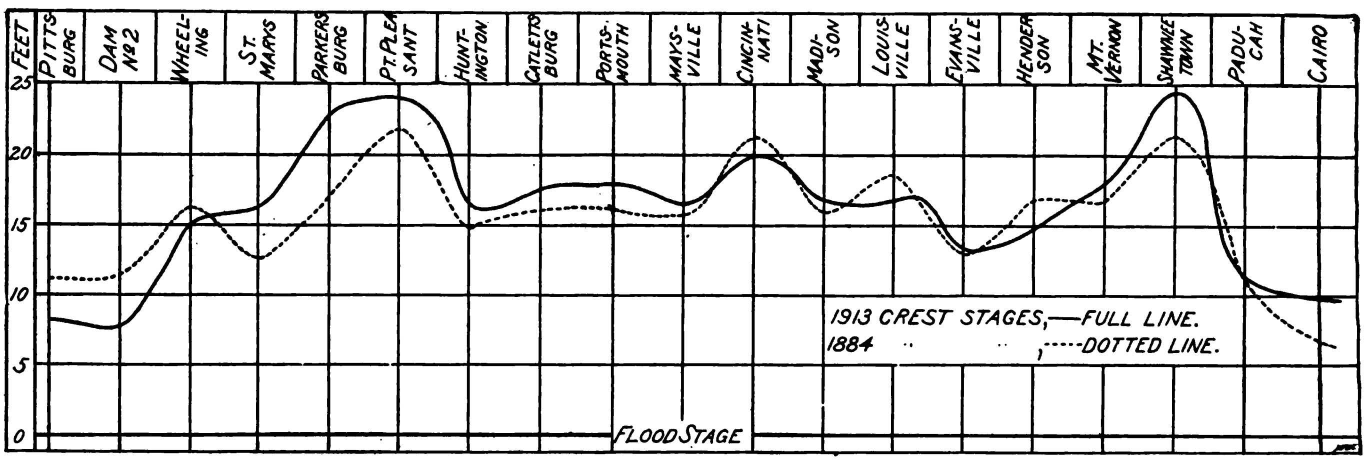


Diagram I.—Comparison of crest stages in the Ohio River in floods of 1884 and 1913.

Temperatures in degrees Fahrenheit in the Ohio Valley at 7 a. m. Washington mean time, Feb. 4–15, 1884.

Stations.	Dates.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pittsburgh, Pa.	23	35	27	39	60	39	38	42	53	36	43	52	58	40	19
Columbus, Ohio	34	33	33	36	51	38	36	38	45	34	36	40	52	28	20
Cincinnati, Ohio	30	42	36	44	62	46	40	43	48	36	45	48	55	20	20
Indianapolis, Ind.	18	36	40	38	57	37	34	38	36	30	35	42	38	8	18
Louisville, Ky.	29	42	41	49	64	53	39	46	59	35	43	53	47	19	20
Cairo, Ill.	31	39	52	59	63	49	34	43	40	34	42	58	38	15	24
Nashville, Tenn.	32	37	46	60	63	64	46	46	58	43	50	57	57	27	18
Mean	29	38	39	46	60	47	38	42	48	35	42	50	49	23	20

The temperatures given in the above table are all from places situated in the lowlands, but the corresponding temperatures even at the highest points in the watershed and on the north slopes must have been at least 10 degrees above the freezing point. The relatively high temperatures and the fact that in the month previous to the flood there was an average of about 2 feet of snow in Ohio, West Virginia, and western Pennsylvania must enter very largely into any consideration of the cause of the 1884 flood. Unfortunately, the snowfall records of 30 years ago are very deficient as to number and unsatisfactory as to quality, but enough is known to state that at the time of the thaw there was practically no snow on the ground immediately

along the Ohio River in Ohio, Indiana, and Kentucky, and perhaps for a distance of 100 miles back from the river. There was still some snow on the ground in northern Ohio, West Virginia, and western Pennsylvania, and doubtless a very considerable amount in the higher altitudes of those regions. There are, however, no definite records of snowfall available for the confirmation of this view. Gagings of tributary streams were not made at points where such measurements would have been useful in determining the run-off from areas whence no meteorological observations are available. We conclude that there must have been a large run-off from melting snow from the following facts: (1) The rainfall for the entire flood period, viz, February 4 to 14, inclusive, does not seem to have been sufficient to produce the volume of water carried by the river. (2) The known horizontal distribution of precipitation will not account for the high water in the upper reaches of the Ohio; that is to say, the region of heavy precipitation was mostly over the immediate Ohio Valley below Cincinnati. (3) The fact that the Ohio was at flood stage at Cincinnati as early as February 4, the day that the rain began. This last fact in itself clearly indicates that a large quantity of snow water had already entered the stream. In the 1913 flood the Ohio at Cincinnati was at a stage of 22.6 feet on the second day of the rain period, or at an initial stage of about 17 feet lower than at a corresponding period in the 1884 flood.

If the Ohio River on March 24, 1913, had been at, say, a 30-foot stage, which is not unusual for March, a new record of high water would have been written for the Ohio Valley. In this connection it should be kept in mind that torrential rains and severe winter weather are incompatible, and that in the season when heavy rains are probable the rivers and small streams are generally low.

The two floods here considered, so far as known by observation and experience, represent the two diametrically opposite weather conditions under which destructive floods in the Ohio are likely to occur.

TABLE 4.—*Daily precipitation (in inches and hundredths), Feb. 4–14, 1884, Ohio watershed.*

Stations.	4	5	6	7	8	9	10	11	12	13	14	Total.
Pittsburgh, Pa	0.45	0.76	0.80	0.34	0.01	0.04	0.13	0.53	0.06	0.14	0.18	3.44
Wellsburg, W. Va	....	1.50	1.00	0.25	....	....	....	....	....	0.75	0.25	3.75
Helvetia, W. Va	0.71	0.06	0.75	0.31	0.33	0.58	0.62	0.09	0.00	0.14	0.74	4.33
Marietta, Ohio	0.85	T.	1.41	0.11	0.00	0.19	T.	0.89	0.00	0.28	0.56	4.29
Quaker City, Ohio	0.69	1.80	1.95	0.22	0.00	0.16	0.26	0.20	T.	0.99	0.00	6.27
Warren, Ohio	0.00	1.70	0.92	0.00	0.00	0.03	0.00	T.	0.58	0.67	T.	3.90
Ironton, Ohio	0.54	0.37	0.53	0.69	0.00	0.06	0.66	0.54	0.00	0.68	0.39	4.46
Lebanon, Ohio	0.15	1.95	1.25	0.10	T.	0.14	0.00	0.30	0.27	0.60	0.50	5.26
Washington C. H., Ohio	....	....	....	3.74	0.00	0.10	....	....	....	....	1.53	5.37
Cincinnati, Ohio	1.35	1.56	1.65	0.23	T.	0.06	0.14	0.59	0.06	1.18	0.00	6.82
Waverly, Ohio	0.58	0.48	1.74	0.69	T.	0.06	T.	0.91	0.00	0.19	0.45	5.10
Dayton, Ohio	0.55	0.66	1.42	0.00	0.12	0.17	0.02	0.16	0.33	0.90	0.02	4.25
Logan, Ohio	T.	1.28	2.37	0.63	T.	0.04	T.	0.45	0.00	0.46	0.40	5.63
Columbus, Ohio	0.58	0.55	1.40	0.07	....	0.07	0.02	0.26	0.06	0.55	0.02	3.58
Levering, Ohio	0.92	0.00	1.55	0.00	0.50	0.00	0.00	0.45	0.00	1.02	0.00	4.44
Canton, Ohio	0.52	0.33	1.07	0.03	0.02	0.12	0.00	0.15	0.07	0.60	0.47	3.38
Granville, Ohio	0.27	0.60	1.95	0.00	0.00	0.10	0.00	0.20	0.00	0.30	0.70	4.12
Westerville, Ohio	0.53	1.11	0.31	0.02	0.09	0.03	0.19	0.24	0.26	0.51	0.00	3.29
Wooster, Ohio	....	....	1.87	0.00	....	0.34	0.00	....	....	0.71	0.00	2.92
Sidney, Ohio	0.26	....	1.25	0.04	0.11	0.22	0.01	0.14	0.20	0.59	....	2.82
North Lewisburg, Ohio	0.45	0.45	1.25	0.00	0.10	0.20	0.10	0.10	0.25	0.55	0.25	3.70
Cleveland, Ohio	0.31	1.22	0.63	0.01	0.04	0.51	0.00	0.45	0.15	0.57	0.02	3.91
Oberlin, Ohio	0.20	1.18	0.61	....	0.07	0.28	0.00	0.24	0.46	0.55	....	3.59
Wauseon, Ohio	0.22	1.27	0.32	0.03	0.03	0.22	0.00	0.34	0.77	0.18	0.00	3.38
Junction (Paulding County), Ohio	0.24	0.86	0.36	0.03	0.08	0.27	0.00	0.48	0.45	0.23	0.00	3.00
Sandusky, Ohio	0.20	1.04	0.65	0.05	0.06	0.30	0.00	0.83	0.32	0.42	0.04	3.91
Upper Sandusky, Ohio	0.00	2.02	0.70	....	0.00	0.41	0.00	....	....	0.88	0.00	4.01
Toledo, Ohio	0.04	0.90	0.28	0.00	0.07	0.08	0.00	0.10	0.37	0.19	0.00	2.03
Vevay, Ind	....	1.55	3.50	0.20	0.00	0.00	0.07	0.00	0.90	0.00	0.62	6.84
Jeffersonville, Ind	0.84	(1)	(1)	3.98	0.00	0.18	....	1.13	0.39	T.	....	6.52

[1] Probably included in the following day.

TABLE 4.—*Daily precipitation, Feb. 4–14, 1884, Ohio watershed*—Continued.

Stations.	4	5	6	7	8	9	10	11	12	13	14	Total.
Laconia, Ind	0.90	0.00	0.00	4.11	0.00	0.14	0.00	1.00	0.41	0.55	0.00	7.11
Sunman, Ind	....	2.00	1.38	0.00	0.00	0.25	0.00	0.32	1.15	0.38	....	5.48
Indianapolis, Ind	0.43	0.81	0.63	0.04	0.09	0.31	0.04	0.08	0.77	0.17	0.00	3.37
La Fayette, Ind	(1)	1.18	0.00	0.35	0.26	T.	0.00	(1)	1.39	0.43	0.00	3.61
Logansport, Ind	(1)	1.02	0.00	0.00	0.33	0.00	0.00	(1)	0.75	0.65	0.00	2.75
Rising Sun, Ind	(1)	(1)	(1)	2.85	0.00	0.25	0.00	0.40	0.00	0.35	....	3.85
Terre Haute, Ind	(1)	2.03	0.83	0.00	0.00	0.59	0.00	0.17	0.02	0.00	....	3.64
Wabash, Ind	(1)	1.10	0.35	0.00	0.01	0.20	0.00	0.00	0.00	1.36	....	3.02
Evansville, Ind	0.00	0.50	0.60	1.50	0.27	0.60	0.00	0.47	0.30	0.10	0.47	4.81
Louisville, Ky	0.89	2.38	1.73	0.63	0.00	0.14	0.61	0.60	0.27	0.77	T.	8.02
Frankfort, Ky	1.23	0.40	1.91	0.70	0.00	0.10	0.00	0.97	0.03	1.23	0.00	6.59
Bowling Green, Ky	(1)	(1)	2.73	0.00	0.00	0.00	0.00	0.90	0.00	0.69	0.44	4.76
Cairo, Ill	0.07	1.17	1.24	0.18	0.25	0.03	0.51	0.11	0.13	0.43	0.01	4.13
Springfield, Ill	0.57	0.37	0.03	0.03	0.16	0.12	0.10	0.40	1.14	0.40	0.00	3.32
St. Louis, Mo	1.32	0.40	0.37	0.02	0.24	0.03	0.08	0.25	1.15	0.16	0.00	4.02
Memphis, Tenn	T.	0.57	2.41	0.53	1.53	0.56	0.59	0.05	0.42	0.37	0.00	7.03
Dyersburg, Tenn	(1)	(1)	3.42	....	....	0.80	1.90	0.25	0.26	0.34	0.00	6.97
Grief, Tenn	0.00	(1)	(1)	3.00	0.00	2.12	0.00	0.00	0.00	1.57	0.00	6.69
Gadsden, Tenn	0.00	0.72	2.30	0.52	0.57	0.92	0.86	0.07	0.10	0.53	0.00	6.59
Bolivar, Tenn	0.00	(1)	(1)	2.02	0.00	1.67	0.42	0.28	0.00	0.49	0.00	4.88
Milan, Tenn	0.10	1.71	0.70	0.44	0.95	0.70	0.25	0.02	0.47	0.25	0.00	5.59
McKenzie, Tenn	0.57	1.40	1.10	0.10	0.70	0.00	0.75	0.25	0.30	0.00	0.00	5.17
Nashville, Tenn	0.04	T.	1.73	0.68	0.74	0.44	0.25	0.01	0.53	1.08	0.00	5.50
Chattanooga, Tenn	0.00	0.00	0.04	3.19	1.21	0.52	0.12	0.01	T.	1.23	0.05	6.37
Knoxville, Tenn	0.22	0.00	0.01	1.53	0.78	1.97	0.33	0.02	0.00	0.61	0.38	5.85
Jonesboro, Tenn	0.30	0.00	0.01	0.85	0.60	0.65	0.08	0.70	0.00	0.17	0.98	4.34
Greenville, Tenn	T.	T.	0.00	T.	T.	1.10	1.30	0.40	0.00	0.50	0.90	4.20
Maryville, Tenn	0.10	0.00	0.00	1.92	2.86	0.31	0.64	0.00	0.00	2.23	0.00	8.06
Andersonville, Tenn	0.00	0.00	0.00	1.55	1.76	1.09	0.26	0.00	0.12	0.29	1.29	6.36
Caryville, Tenn	0.00	0.00	0.00	1.90	1.26	1.36	0.00	0.00	0.00	1.90	0.00	6.42
Parksville, Tenn	....	....	T.	3.00	1.80	T.	0.34	0.00	T.	1.30	0.00	6.44
Ashwood, Tenn	....	0.80	1.20	0.50	0.70	0.20	0.00	1.00	0.70	0.10	0.00	5.20
Austin, Tenn	0.25	0.00	0.50	1.45	0.00	0.00	1.40	0.00	1.20	0.70	0.00	5.50
Mean	0.29	0.69	0.93	0.72	0.30	0.35	0.21	0.29	0.28	0.57	0.19	4.82

(1) Probably included in the following day.

The 1884 flood is typical of the midwinter flood that results from moderately heavy precipitation in conjunction with the melting of snow and the breaking up of ice in the rivers. It seems remarkable that so few midwinter floods have occurred in the past.

The great flood of 1832, so far as can be ascertained, was a midwinter flood; and these two, 1832 and 1884, seem to have been the only typical midwinter floods of record in the 81 years which have passed since 1832. Other midwinter floods are produced by continued heavy precipitation during an open winter, as in January, 1913 (see Chart No. 2), in which the accumulated rainfall in the Ohio watershed January 1–13, 1913, is shown. The origin of the great majority of floods in the lower Mississippi can be traced back to the accumulated precipitation in the lower Mississippi and Ohio Valleys during January, February, and March.

The flood of March and April, 1913, is in a class by itself; it responds to the condition; unprecedented rains plus high run-off with rivers at a medium stage. As in the case of midwinter floods all of the factors in the expression for the 1913 flood are variables, and we therefore do not know whether or not the upper flood limit has yet been reached.

Ordinarily the intensity of rainfall varies inversely as the duration; it is the exception that heavy rains continue over areas as large, for example, as the State of Ohio, for more than 24 hours. In October, 1910, however, rains fell almost continuously over the lower Ohio Valley for a period of 4 days, although the period of great intensity really covered only 3 days. As the aggregate rainfall for this storm in some localities was equal to that which fell over parts of Ohio during March, 1913, a chart showing its horizontal distribution has been prepared and is presented as Chart No. 3 in the series of precipitation charts accompanying this report.

We distinguish, of course, between the conditions of the soil as to moisture content and the stages of the streams in March and October, respectively. The bulk of the rain in the October storm fell in the lower stretches of the Ohio Valley and doubtless the gage readings at Cairo, Ill., and Evansville. Ind., will give us an idea of the amount of water which ran into the streams as a result of the heavy rains. The Ohio at Cairo, Ill., on October 4, when the rains began, was at a stage of 12.2 feet; it rose steadily until the 11th, when a stage of 26.8 feet was reached, after which it fell steadily until the end of the month. At Evansville, Ind., the Ohio rose from 4.7 feet at 7 a. m. on October 4, to 26 feet at noon of the 9th, a total rise of 21.3 feet, due to the heavy rains of October 3–6.

Considering that the rains on the dates mentioned were almost as heavy and continuous as those of March 23–27, 1913, it is interesting to note that the effect on the streams was scarcely noticeable as compared with the effect of the last-named floods. The maximum discharge in the Ohio at Evansville, in connection with the October, 1910, rains, was approximately 250,000 second-feet on October 9, whereas, the approximate discharge at Evansville on March 25, 1913, the second day after the beginning of the rains, was, according to figures supplied by the United States Geological Survey, a little greater than the above figures, and reached a maximum value of 676.000 second-feet on April 5. From these figures it would seem reasonable to infer that in those seasons when the supply of water in both the soil and the streams is at a low ebb, as must be the case late in summer and throughout the autumn, little is to be feared from floods in the great rivers, due to heavy rains. Danger from local floods in the smaller streams is, however, an ever present possibility.

Before closing the question of summer floods in the Ohio we would remark that practically the only semblance to a midsummer flood, as determined by the stages at Cincinnati, Ohio, occurred in August, 1875, when the river rose above the 50-foot stage and remained above that stage for five days, culminating at 55.3 feet on August 6. This flood was caused by heavy rains in July, which produced moderately high stages in the Ohio during the latter part of that month. A short period of heavy rains in the first part of August made the attainment of flood stages possible. In the smaller streams, as before indicated, flood stages are possible in the summer and autumn months, though relatively infrequent.

Are floods in the Ohio increasing? That question has received a great deal of attention in recent years and several writers have answered it in the affirmative, citing the Ohio River as an example of greater flood frequency now than formerly.

The writer has not been able to discover valid reasons for sharing in that belief; on the contrary a careful consideration of the data for the Ohio River leads to the opinion that while the data on the subject are inadequate to the formation of a definite conclusion, such as are available, can be so arranged as to point to either an affirmative of a negative conclusion, as will be shown later in this paper.

It must be admitted that atmospheric precipitation is the sole source of the water which fills the streams. Meteorologists have known for many years that that element is variable both in time and space. The one other cause which enters largely in flood formation is the character of the surface covering in a watershed. It is conceivable that if the character of the surface cover be suddenly changed there might be a profound change in the run-off, but since all artificial changes in a river system are brought about slowly, and since some of them may augment the run-off while others may retard it, it becomes a matter of great difficulty to integrate the total effect of artificial changes in the watershed or stream flow for any given epoch. The Department of Agriculture is now carrying on experimental work in the Rio Grande Forest Reserve that, when completed will throw considerable light upon the subject.

The writer has had occasion to examine the precipitation records of the United States as collected in the beginning by the Smithsonian Institution, and later by the United States Signal Service and its successor, the present Weather Bureau of the Department of Agriculture. A brief reference to the results of that examination will be useful in connection with the present subject.

The total yearly precipitation varies greatly even at points but a short distance apart; it therefore becomes a difficult matter to express the monthly or annual abnormality for an area so large as the United States. For convenience in discussion the latter area has been divided into 19 smaller climatic units and it is only through a combination of the results for the several smaller units that one can get an idea of the abnormality of the country as a whole. Since systematic observations began there has not been a single year when precipitation was above normal in all parts of the country, and but one year when it was deficient in all parts of the country in one and the same year. The abnormalities for the smaller climatic units, since the units are of unequal size, do not readily lend themselves to a combination, but considered separately they indicate the interesting fact that in the Rocky Mountain region from Montana southward to the Mexican border the number of years with precipitation above the normal are very nearly equal to the number of years with precipitation below the normal. East of the Mississippi, and in the Gulf and South Atlantic States, especially, the number of years with diminished precipitation are in a very decided majority. Further, it would seem that years of fat or lean precipitation do not follow any recognizable sequence and that the most probable value for any year is not the arithmetical mean or normal for the latitude, but a value near and slightly below the mean. On the other hand years of excessive rainfall do not occur with the same frequency as years of light rainfall; heavy rains seem to be due to extraordinary and probably world-wide temperature and pressure relations which appear to be the cause of unusual storm movement with its attendant precipitation. Thus in 1912 the prevalence of an unusually large number of southwest storms and the rains attending them produced the great flood in the lower Mississippi Valley of 1912.

In a previous discussion of the subject of secular variation of precipitation[1] the writer prepared from the records of three stations in the middle Ohio Valley, Cincinnati, Portsmouth, and Marietta, Ohio, a diagram which he called "progressive averages of precipitation for the Ohio Valley." The curve in that diagram has been brought down to date and is presented below in Diagram II. It was prepared as follows: The annual precipitation at the three points named was combined in a single mean, which may be considered as a regional mean for that part of the Ohio Basin between Marietta and Cincinnati. It probably represents with considerable accuracy a region of 300 or 400 miles in all directions from the river as a central point, but it is not claimed that the figures represent the precipitation of the entire watershed.

The heavy horizontal line in the diagram represents the normal precipitation; where the curved line passes above the horizontal line precipitation was above the normal by amounts shown in the scale on the left margin. The diagram is conveniently read by considering the peaks as wet spells and the valleys as dry spells. This diagram is similar to others of a like character which have been constructed for different sections of the country in the fact that it shows that years of fat and lean precipitation follow each other at very irregular intervals and further that the period of fat or lean rains may extend over very unequal periods; thus the period 1841–1849 in the diagram was a period of fat rains which has not since been equaled. Likewise the memorable drought of 1838 in the Ohio Valley is indicated by the character of the curve for 1837–1839. Another important point to remember is that the peaks of fat rains in the Ohio Valley do not ordinarily coincide in point of time with similar peaks for the region west of the Mississippi or along the Gulf of Mexico. In other words, the variation of precipitation in regard to space is largely local rather than general. The variations with respect to time are exceedingly irregular. At this point it is proper to mention that the calendar year is much too great a unit for comparative purposes; unfortunately the labor of assembling the data in a more convenient unit is so great as to be prohibitive.

In Table No. 1 we have assembled all of the floods of consequence in the Ohio River from its source at Pittsburgh, Pa., to its mouth at Cairo, Ill. We will now proceed to consider that record in connection with the rainfall curve of Diagram II.

[1] Bulletin D, Weather Bureau, 1897, p. 18.

In the endeavor by others to show that floods in the Ohio are increasing the record of river stages of 22 feet or more at one point in the river, Pittsburgh, Pa., for the 40 years 1870–1910 has been considered. It was assumed that a stage of 22 feet, which, by the way, is the point at which the river begins to overflow its banks and is known as the flood stage, constituted a flood. The number of these so-called floods which occurred in the first half of the 40-year period was compared with the number which occurred in the second half. The result of the count was that the number in the second half of the period considerably exceeded the number in the first half; therefore the conclusion that floods in the Ohio River are increasing.

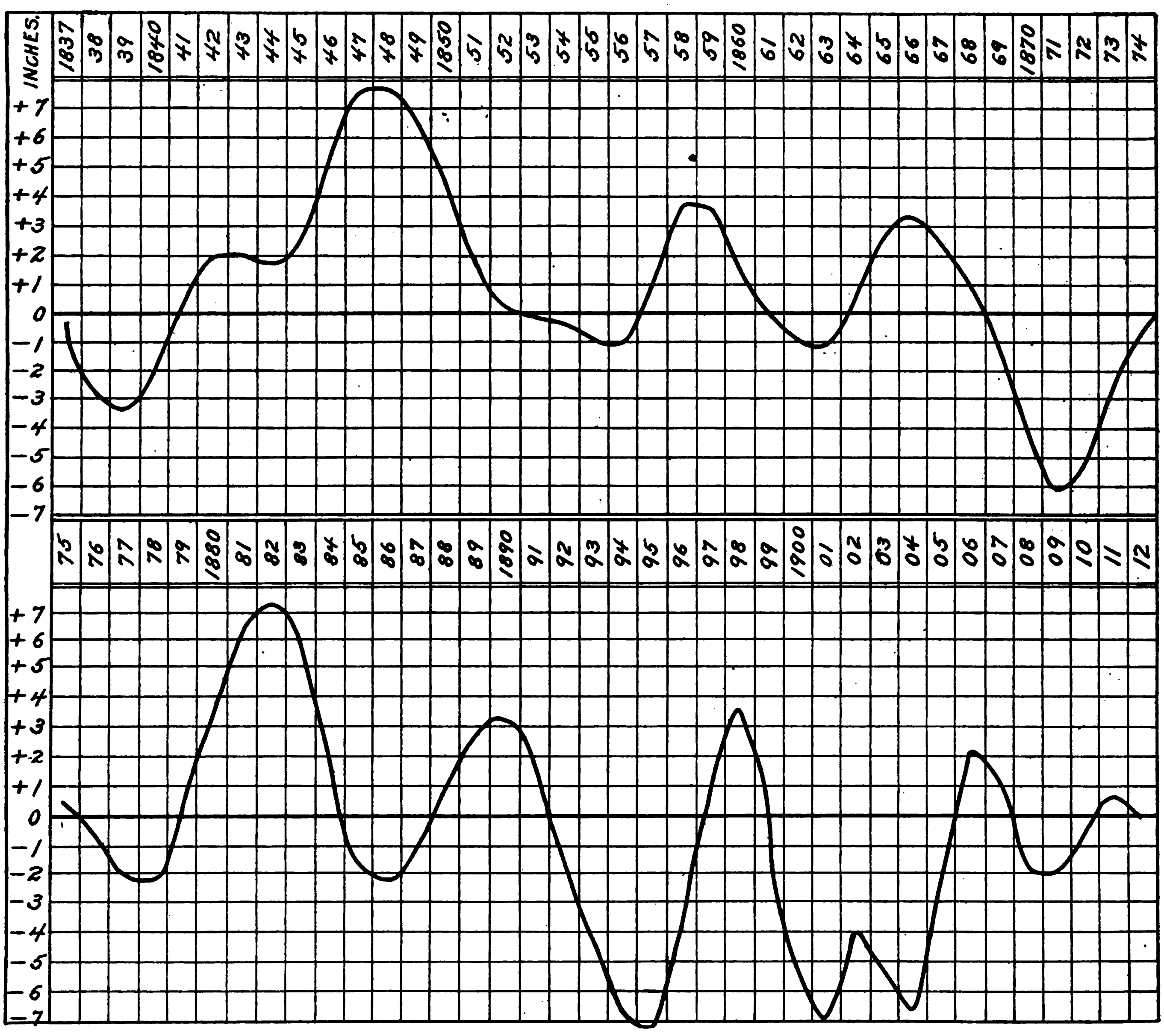


DIAGRAM II.—Progressive averages of precipitation in the Ohio Valley.

There are certain obvious objections to this procedure; in the first place, a rise in the river to the flood stage does not constitute a flood; the flood stage is simply the point on the gage when the river *begins* to overflow and cause damage to property on its banks; in the second place, as has already been pointed out in this paper, a river in flood at one single point in its course is not necessarily in flood at other points; therefore it is not proper to determine

flood frequency from a single point in a river's course; in the third place, no account has been taken of the precipitation during the period under consideration.

By reference to Diagram II we see at once that there was a period of dry years extending from about 1869 to 1880, with the single exception of two years of about normal rainfall in 1875 and 1876. The deficiency for 1870 and 1871 was well marked and extended over the entire watershed. We are therefore justified in the assertion that the lack of floods in the Ohio above Cincinnati during the 10 years 1870–1880 was due simply to a term of dry years. Considering further Diagram II, we see that a period of increased precipitation set in in 1880, culminating in 1882. The well-known floods of the early eighties in the Ohio Valley have already been described in this paper. The next period of heavy precipitation centered in 1890, but it was confined practically to a single year and caused serious floods only in the lower stretches of the river. (See Table No. 1.)

The precipitation after 1890 was markedly deficient, especially during the drought years of 1894–95. A second short period of abundant rains centered in 1897–98. Serious floods occurred in both of these years. Then followed a term of dry years, which continued until 1906. No serious floods occurred until 1907. The agreement between the record of precipitation and flood frequency is seen to be as close as might be reasonably expected. Let us next consider the record of serious floods in the Ohio as contained in Table No. 1.

Dividing the 40-year period into two equal portions, it is seen, as before stated, that the greater number of floods occurred in the second half; but we have just shown that the absence of floods between 1869 and 1880 was due to a lack of precipitation. If we now disregard the first 10 years of the period and divide the remaining 30 years into two equal periods of 15 years each and count the floods therein, we have the result shown in tabular form below:

Number of severe floods in the Ohio River during the 40 years, 1870–1910, in two periods of 20 years each and also in two periods of 15 years each.

Stations.	First period of 20 years, 1870–1890.	Second period of 20 years, 1891–1910.	First period of 15 years, 1881–1895.	Second period of 15 years, 1896–1910.
Pittsburgh	2	9	3	8
Cincinnati	6	7	8	5
Louisville	5	5	7	3
Evansville	6	11	8	9

The Cairo stages are not included in this table since they are influenced by causes other than the amount of water coming down the Ohio and therefore would be misleading.

The above is a very interesting and instructive table; we see at once that if we use the Pittsburgh stages as indicative of the number of floods in the Ohio there is a preponderance of floods in the second 20 and 15 year periods, respectively, but if we use Cincinnati the division into 20-year periods shows about an equal number in each; if we disregard the first 10 years of the period and divide the remaining 30 years into two equal portions, we find the result of the Pittsburgh count is reversed, and that the preponderance of severe floods falls within the first period. The same results are reached if we consider the Louisville record, but Evansville, the next station below Louisville, coincides with Pittsburgh, but for entirely different reasons.

The facts here given and the interpretation put upon them will have served the purpose of this paper if attention be focused upon what seems to be an obvious conclusion, viz, that flood frequency is primarily due to the distribution of precipitation as regards both time and space, and that there is urgent need of accurate measurements both of precipitation and stream flow for the next 50 years or longer before conclusions the one way or the other may be reached.

PROBABLE MAXIMUM FLOOD IN THE OHIO AT PITTSBURGH.

In approaching a problem of this character we can be guided only by observation and experience. The Ohio at Pittsburgh has been under systematic daily observation a little more than 60 years, while records of floods dating back to the beginning of the nineteenth century are available. The extreme flood height in the last 100 years was 35.5 feet, on March 15, 1907. That stage was produced not by torrential rains over the entire watershed, but by the concurrence of two favorable conditions, the first of which was effective over a comparatively small portion of the entire Allegheny-Monongahela Basin, viz, the watersheds of the Kiskiminetas and Youghiogheny Rivers. These two conditions were, first, the occurrence of a moderately heavy fall of snow on March 10, 1907, over the watersheds above named; second, the occurrence two days later of rain with rising temperature. The rain, which began on the 12th, was practically continuous for 48 hours, 2.41 inches falling at Pittsburgh, Pa., and the average for the entire watershed was 1.97 inches. While the rainfall extended over the entire watershed, it was heavy only in the neighborhood of Pittsburgh. The snow that made extremely high water probable was likewise confined to the watersheds of the Kiskiminetas and Youghiogheny. While the synchronism in the time of the several flood waves reaching Pittsburgh in this case was not perfect, it was nearly so, and there was produced the highest water of a century on the Pittsburgh gage on barely 2 inches of rainfall on the average for the entire watershed.

The midwinter flood of 1884 was likewise due to a winter thaw in connection with only moderately heavy rains, but the volume of water which passed down the Ohio River in that flood was greater than in the 1913 flood, although the rainfall over the basin was probably not more than half as great as in 1913. The record of the 1884 flood illustrates the potentiality of snow covering as a factor in flood causation, and this fact is again emphasized in the record of the flood of March 1, 1902, when a stage of 32.4 feet was reached at Pittsburgh, Pa., on an average rainfall over the entire watershed of three-quarters of an inch. In this case the ice came out of the rivers converging at Pittsburgh separately, else a still higher stage might have been recorded.

The danger of stages above 36 feet on the Pittsburgh gage seems to lie mostly in the probability of ice gorges in both rivers breaking up simultaneously. That long-continued rains, such as fell over Ohio and Indiana in March, 1913, may occur over some portion of the Allegheny-Monongahela watershed within the next hundred years is within the range of probability, but that such rains will be uniformly heavy over the entire watershed we consider only as a remote possibility. We consider the formation of ice gorges and their simultaneous breaking up in connection with spring rains to be the greatest flood menace in the upper Ohio Valley.

Perfect synchronism in the breaking up of ice in the streams above Pittsburgh would doubtless cause a stage close to 38 feet on the Pittsburgh gage, and we would consider that figure as the probable maximum flood stage at Pittsburgh. However, if the watersheds of all the rivers above Pittsburgh were to receive as great a rainfall as occurred over Ohio and portions of Indiana in the flood of March, 1913, it is probable that a stage above 40 feet would be reached at Pittsburgh.

FLOOD IN THE LOWER MISSISSIPPI RIVER.

The condition of the Mississippi River as to gage heights on March 31, 1913, or when the crest of the Ohio flood was eight to ten days distant, is shown in the small table below:

Station.	Flood stage.	Stage Mar. 31.	Difference.
	Feet.	*Feet.*	*Feet.*
St. Paul, Minn	14	1.4	−12.6
Dubuque, Iowa	18	10.2	− 7.8
St. Louis, Mo	30	23.2	− 6.8
New Madrid, Mo	34	39.7	+ 5.7
Memphis, Tenn	35	36.0	+ 1.0
Vicksburg, Miss	45	39.6	− 5.4
New Orleans, La	18	14.5	− 3.5

Thus it will be seen that the river was considerably below the flood stage at St. Louis and thence northward to St. Paul, but it was above flood stage at Memphis and thence to Cairo, and rising slowly from Memphis to New Orleans. Moreover, the western tributaries were at moderate stages, and neither high water nor floods were impending in any one of them. It was apparent at the outset, therefore, that, barring additional precipitation, the only water to consider in estimating the volume of the flood in the lower Mississippi was that coming out of the Ohio. As soon as the probable output of the Ohio could be determined it became evident that the flood of 1912 in the lower Mississippi would be equaled, if not overtopped, and warnings to that effect were issued by the Weather Bureau official at Memphis as early as March 27, 1913, about two weeks before the arrival of the flood crest. Warnings were issued at the New Orleans station on March 31 and repeated at intervals as the changing conditions demanded until May 14. The river at Memphis reached the flood stage of 35 feet on March 30 and continued to rise about a foot per day until April 10, when a maximum stage of 46.5 feet, the highest of record, was attained. This stage was a foot and two-tenths above the high water of 1912. On April 10 a break occurred in the levee at Wilson, Ark., above Memphis. The water escaping through this break, in connection with the flow through a previous break at Graves Bayou, on the Arkansas side below Memphis, caused a fall in the river at Memphis of a foot between 8 a. m. and 4 p. m. of April 10. There was no recovery in the river from the effect of the above-mentioned breaks, and the river passed below the flood stage at Memphis by April 29.

The situation at Memphis just before the break occurred was indeed ominous. The levees had withstood a flood earlier in the year and were for the second time within a space of less than two months again subjected to the strain of a volume of water greater than ever before experienced; portions of the city were already flooded; gas was shut off; westbound train service was discontinued; when to add to the peril of the situation heavy rains began to fall in Arkansas, portions of Louisiana, Mississippi, and in western Tennessee. At Little Rock 9.56 inches fell in 24 hours; curiously enough the effect of that great amount of rain on the Arkansas at Little Rock was not great, the total rise amounting to but 9 feet five days later. Evidently the downpour was local in character. At Memphis there was a fall of 3.22 inches in 24 hours on April 9, the day previous to the crest stage.

The crest stage at Memphis, had not the levees given way, would probably have been somewhat higher than was actually recorded. (On this point see p. 90.)

Comparative statistics of floods in the lower Mississippi River published in Weather Bureau Bulletin Y show that the crest stages of the 1913 flood exceeded previous crest stages from New Madrid, Mo., to Helena, Ark.; also at Natchez, Miss.

The facts which conspired to produce lower crest stages in the New Orleans district than were experienced in 1912 were (1) a very slow return of Lake St. John crevasse water, thus enabling the bulk of the flood waters in the Mississippi to pass the mouth of the Red River before the arrival of the crest of the crevasse water, and (2) a short period of northerly winds about May 11, 1913, which tended to augment the discharge of the flood waters into the Gulf of Mexico.

The duration of the flood is shown in the small table below, in which similar statistics for 1912 are given for comparative purposes:

Duration of 1912 and 1913 floods.

Stations.	Number of days above flood stage.			
	1912	1913		
		First flood.	Second flood.	Total.
Cairo, Ill.	45	20	27	47
Memphis, Tenn.[1]	56	25	30	55
Helena, Ark.	62	25	34	59
Arkansas City, Ark.	61	21	33	54
Vicksburg, Miss.	62	25	38	63
Natchez, Miss.	63	20	37	57
Baton Rouge, La.	69	18	41	59
Donaldsonville, La.	66	16	37	53
New Orleans, La.	60	9	37	46

[1] On Mar. 1, 1912, flood stage changed from 33 to 35 feet; the latter value was used in this table.

In forming the table the two floods in 1913 are considered separately and the total number of days above the flood stage for both floods is given. Thus we discover that so far as duration is concerned the combined number of flood days in 1913 is somewhat short of the number of flood days in 1912. It seems, therefore, that notwithstanding the higher crest stages in 1913 than in 1912 the volume of the latter flood was really the greater of the two.

The overflowed area in 1912 also appears to have been considerably greater than in both floods of 1913.

Area overflowed.—The area of overflowed lands, whether from crevasse water or backwater, was less from the two floods of 1913 than from the single flood of 1912.

In the Memphis district, Cairo to Helena, the levees did not break in January, 1913, and consequently very little damage from overflow was sustained. The only crevasse of any importance in the January, 1913, flood occurred in the Vicksburg district near Beulah, Miss., the scene of a serious break in the levee in 1912. Repairs to the 1912 break had not been wholly made when the January, 1913, flood reached that point. At first the break had a width of but 200 feet, but a rise of 6 feet additional in the river caused the break to widen to about 1,000 feet in spite of efforts to restrain it within its original bounds. Efforts to prevent the break attaining a greater width were, however, successful, and the resulting overflow was only about half of that which occurred in 1912. While the flood waters were still pouring through the crevasse a successful attempt was made to close it. The different stages in the attempt are well shown in the series of halftones reproduced in this report.

Figure 4 shows the crevasse as it appeared in February, 1913.

Figure 5 shows the trestle constructed of piling, and the rock dumped into the break.

Figures 6, 7, and 8 show, respectively, the final steps of dumping earth on both sides of the rock fill.

FIG. 4.—CREVASSE NEAR BEULAH, MISS., IN FEBRUARY, 1913.

FIG. 5.—CLOSING CREVASSE AT BEULAH, MISS., MARCH, 1913.

Trestlework and rock fill.

FIG. 6.—CLOSING BEULAH CREVASSE.

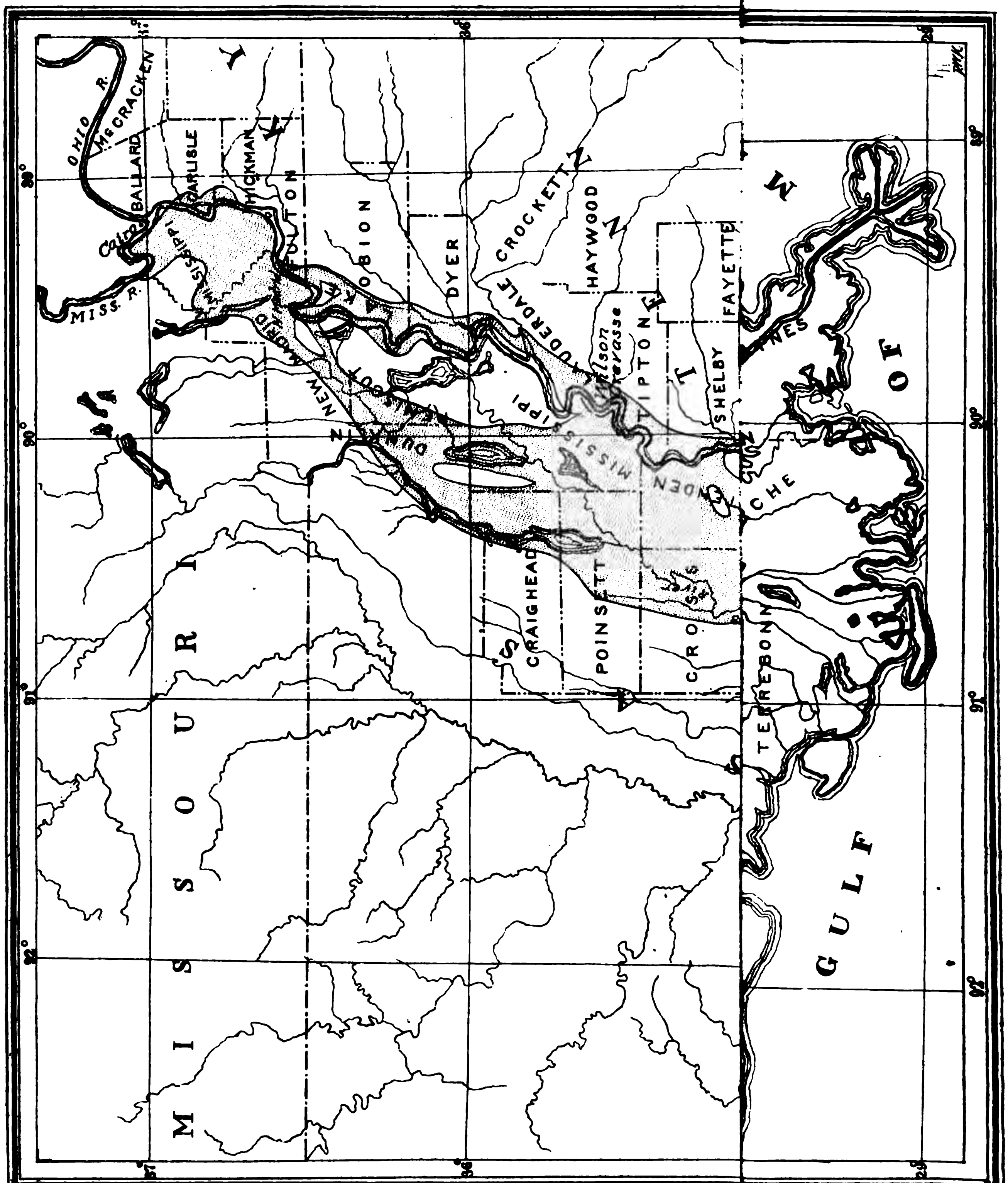
Dumping dirt on river side of rock fill, March, 1913.

FIG. 7.—CLOSING BEULAH CREVASSE. LAND SIDE OF FILL, 1913.

FIG. 8.—CLOSING BEULAH CREVASSE.

Both sides of fill. Note difference in height of water. 1913.

Chart 5, Part 2. **Flooded district** (in red)



The closing of the Beulah crevasse prevented the overflow of about 1,000 square miles that was inundated in 1912.

The overflowed areas in the second 1913 flood comprise portions of southeastern Missouri, especially the counties of Mississippi, New Madrid, Dunklin, and Pemiscot. The total area overflowed in Missouri and Arkansas as computed by the Mississippi River Commission being 2,454 square mines. In Arkansas the overflowed counties were Mississippi, parts of Poinsett. Crittenden, St. Francis, Lee, and Desha. The latter was overflowed in part from a break in White River levee.

In general the overflowed region in Arkansas in 1913 was not greatly different from that of 1912. (For details see report of Section Director H. F. Alciatore, p. 97.)

The overflowed areas in Louisiana were not so large in 1913 as in the previous year. In the parishes of northeastern Louisiana, viz, West Carroll, East Carroll, Morehouse, and Richland there was considerable overflow, principally along the bayous in those districts. In the central-eastern parish of Concordia the overflow was general and it extended westward into Catahoula Parish almost to the lake of that name. There was also a third region of overflow, viz, along the Atchafalaya River below Melville in the parishes of St. Landry, St. Martin, Iberville, Iberia, and Assumption.

On the left bank of the Mississippi River there were overflows in Hickman and Fulton Counties in Kentucky; also in the Reelfoot Lake region of Tennessee and in small portions of Tennessee counties bordering the river.

In Mississippi the counties which were overflowed in whole or in part were, from north to south, Bolivar, Sunflower, Washington, Sharkey, Yazoo, Issaquena, and Warren. There was also some overflow along the Yazoo River in the counties of Tallahatchie, Leflore, and Carroll.

A small scale map showing overflowed areas is presented as Chart No. 5. This map has been reduced in great part from larger scale maps prepared by the Mississippi River Commission, to whom we are indebted for most of the information.

MONEY LOSS DUE TO FLOODS.

The elements of fixed capital that suffered in the floods of March and April, 1913, are chiefly those of railway lines, telegraph and telephone systems, bridges and highways, dwellings and other buildings such as power plants, and factories.

Practically all of the above-mentioned elements suffered loss that will require the outlay of additional capital either to replace the tangible property lost or destroyed, or, in case the loss was not total, to restore the system to its original standard of efficiency. In any event the original investment has been increased by just so much as it cost to replace the property destroyed. Loss was also sustained due to interruption of trade or traffic, the failure of prospective crops, and the suspension of business; moreover, vast sums of money and a great deal of labor was devoted to strengthening the levees along the great rivers and in other protective measures, none of which appears in the final summaries of loss.

Much labor and considerable time has been devoted to the collecting of the statistics of loss here given; the most of which are as accurate as could be had except by an actual census of the situation.

In the case of loss to railroads the majority of the facts were supplied by the responsible authorities directly concerned; in a few cases, however, in the absence of definite figures, recourse has been had to a carefully prepared estimate of the loss. There is therefore an element of uncertainty in some of the amounts that may amount to at least 10 per cent; in the statements of loss of crops both matured and prospective; and of loss due to suspension of business the uncertainty, from the nature of the respective cases, is much greater.

We present first a statement of loss suffered by railroads and telegraph and telephone systems arranged by States wherever possible. In the Mississippi Valley States of Missouri, Arkansas, Louisiana, Mississippi, and Tennessee, it has not been possible to distinguish as between States; the total loss is therefore grouped under the general head Mississippi Valley.

Loss to railroads, telegraph and telephone companies.

State or district.	Loss to railroads.	Loss to telephone and telegraph companies.
Ohio	$6,493,555.00	$1,982,756.00
Indiana	4,812,805.00	9,000.00
Illinois	1,391,544.00	
Kentucky	150,000.00	5,000.00
Mississippi Valley	3,120,661.00	6,423.00
New England	[1] 200,000.00	
Total	16,168,565.00	2,003,179.00

[1] Estimated.

Losses other than to railroads, telegraph and telephone companies.

City or district.	Tangible property, buildings, bridges, highways, etc.	Matured crops.	Farms and farm property, including prospective crops.	Stock and movable property.	Suspension of business.	Total.
Ohio River districts:						
Pittsburgh district	$2,500,000		$25,000		$200,000	$2,725,000
Parkersburg district	2,350,000			$1,000	100,000	2,451,000
Cincinnati district	2,530,200				1,360,850	3,891,050
Louisville district	800,000				500,000	1,300,000
Evansville district	700,000		1,125,000		500,000	2,325,000
Cairo district	810,000	$125,000	150,000	205,000		1,290,000
Mississippi River districts:						
Memphis district	2,203,000	214,040	470,000	998,000	1,720,000	5,605,040
Vicksburg district	500,000	150,000	500,000	125,000	350,000	1,625,000
New Orleans district	13,750	240,000	225,000	12,000	75,000	565,750
Cumberland River at Nashville	157,500	23,200		3,500	23,000	207,200
Upper Hudson and Mohawk Rivers, Albany district	950,000				150,000	1,100,000
Connecticut River Valley and Vermont	37,500					37,500
White River, Ind.	4,659,855		262,500	51,150	622,600	5,596,105
Wabash River, Ind.	10,000,000					10,000,000
Smaller rivers of Ohio	93,865,526		1,412,800	[1] 5,002,000	6,394,078	106,674,404
Total	122,077,331	752,240	4,170,300	6,397,650	11,995,528	145,393,049

[1] Distributed as follows: Farm buildings and fences, $1,352,000; soil washing, $3,300,000; driftwood and débris, $350,000.

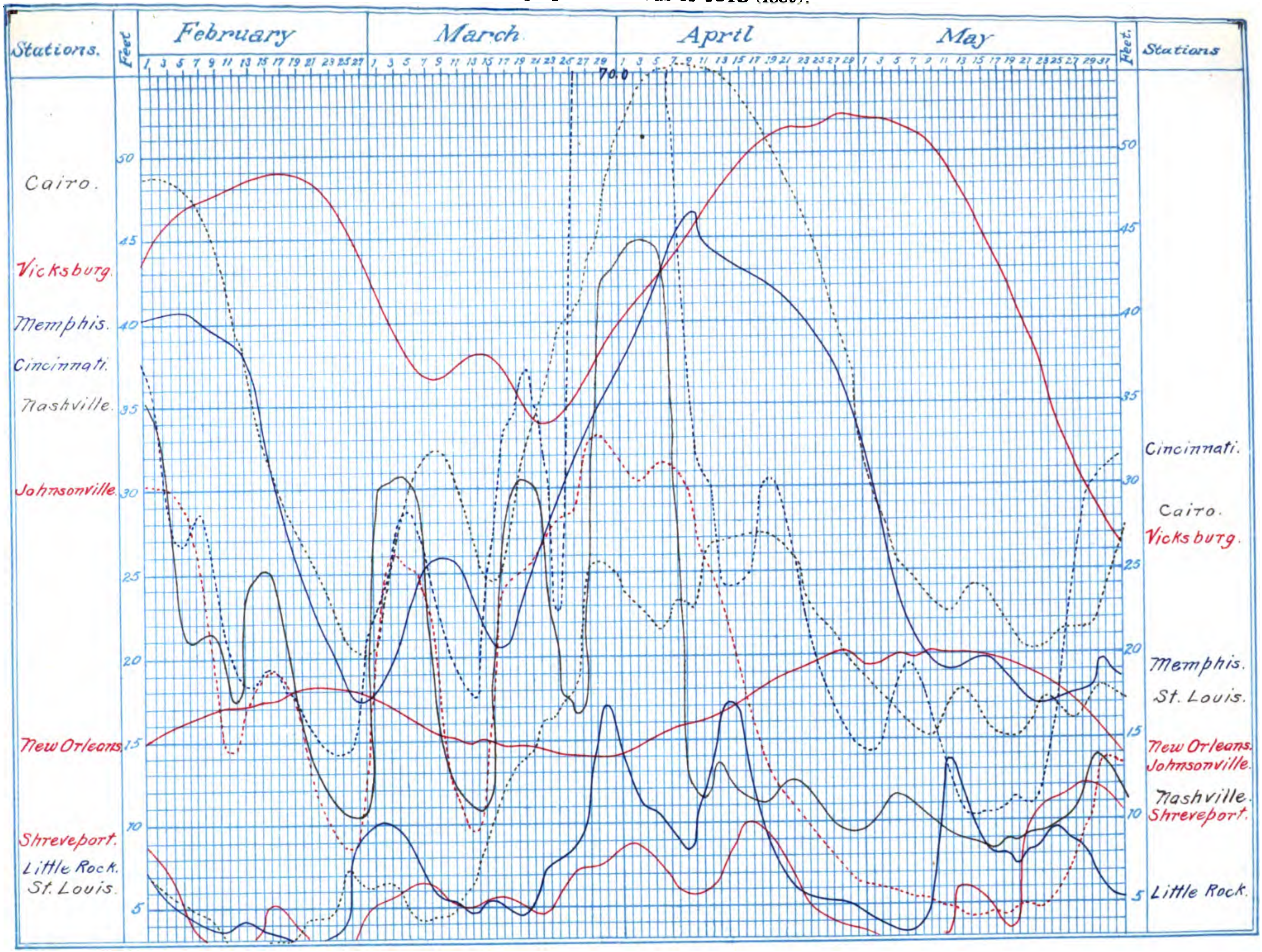
Grand total of loss from all causes, $163,564,793.

The work of the Weather Bureau in the forecasting of floods is frequently referred to in the reports of local forecasters and others in the section which forms the concluding part of this report. No effort has been made to reduce to dollars and cents the saving of property that resulted from the forewarnings of the floods herein described. That such forewarnings are valuable no one will deny, yet there is evidence to show that the full measure of benefits that should have been enjoyed from them was sacrificed, in some cases, because the personal opinion of the recipients differed from that expressed in the bureau's warnings.

If it could be shown that not a single dollar is saved by the flood service of the Weather Bureau, the work would nevertheless be justifiable on the broader ground that it contributes to the general welfare of the people and conduces to the protection of human life.

Diagram IV.

Hydrographs for floods of 1913 (feet).



ACCOMPANYING PAPERS.

DETAILED REPORTS OF FLOODS IN OHIO, INDIANA, ILLINOIS, KENTUCKY, NEW YORK, NEW ENGLAND, AND THE LOWER MISSISSIPPI VALLEY.

Chart 6, Part 2. Total precipitation in Ohio, 8 a. m., March 23, to 8 a. m., March 25, 1913, inclusive (inches).

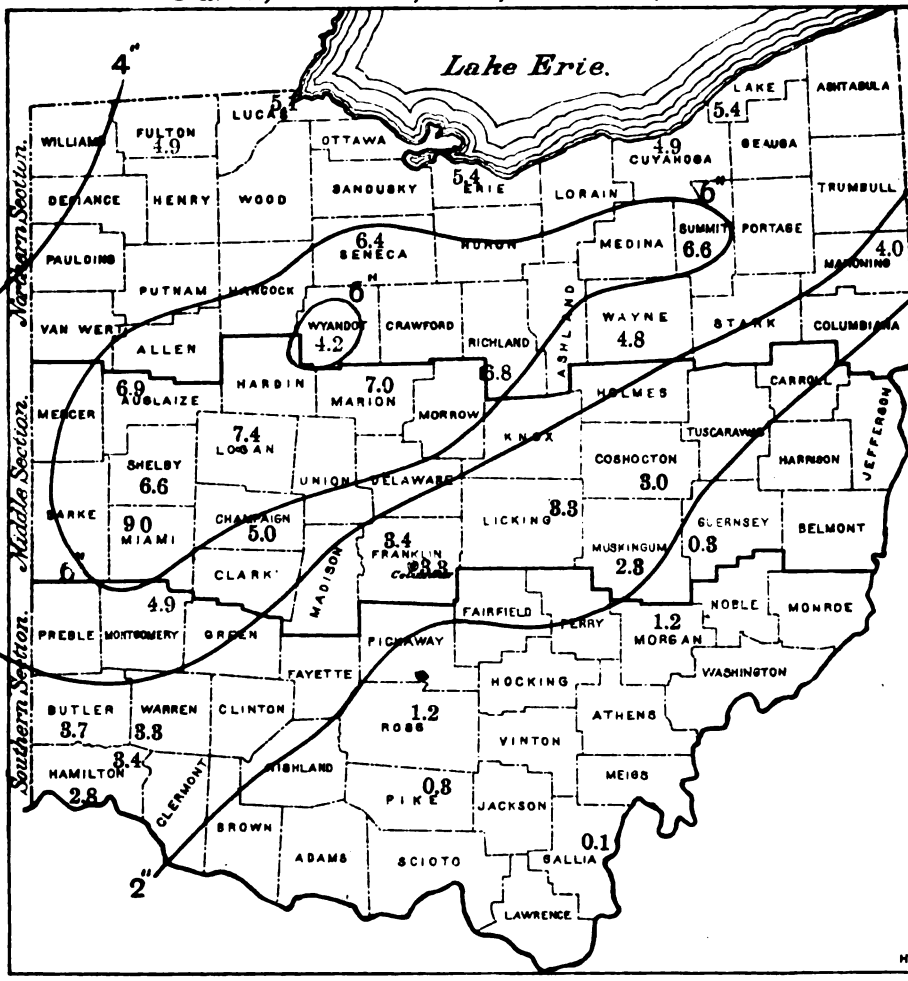


Chart 7, Part 2. Total precipitation in Ohio for 48 hours ending 7 p. m., March 25, 1913 (inches).

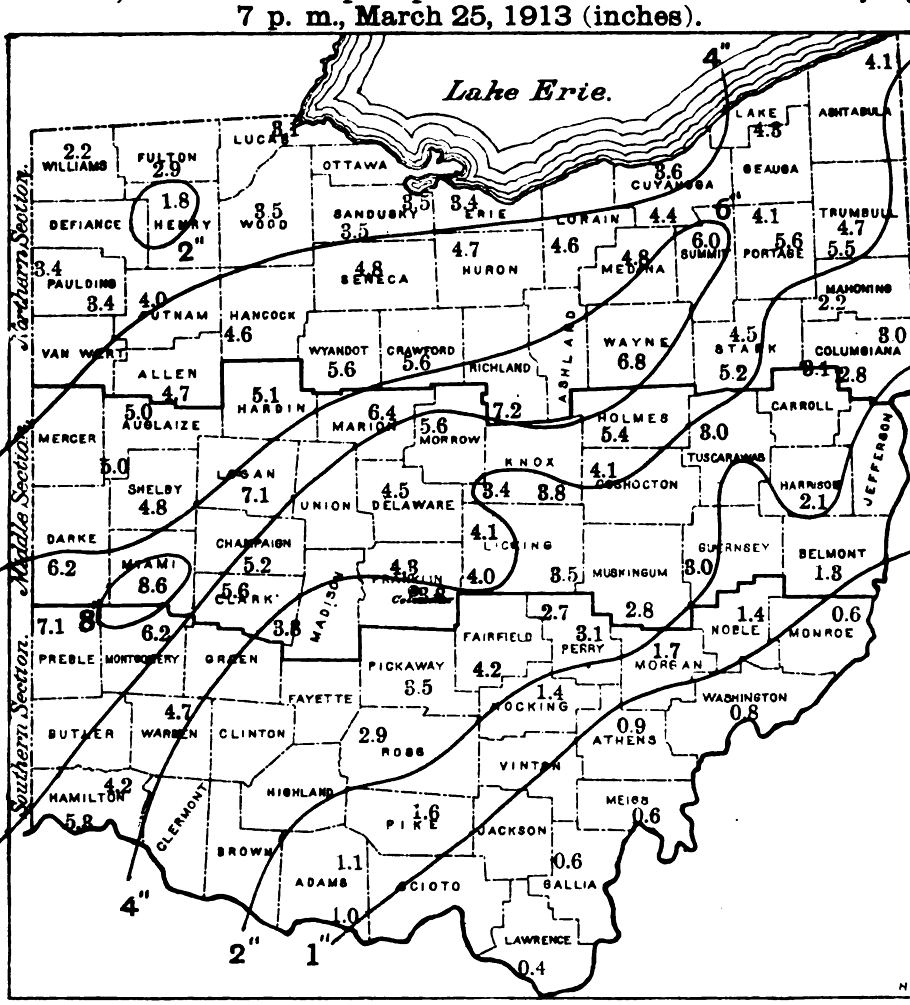


Chart 8, Part 2. Total precipitation in Ohio, 8 a. m., March 23, to 8 a. m., March 27, 1913, inclusive (inches).

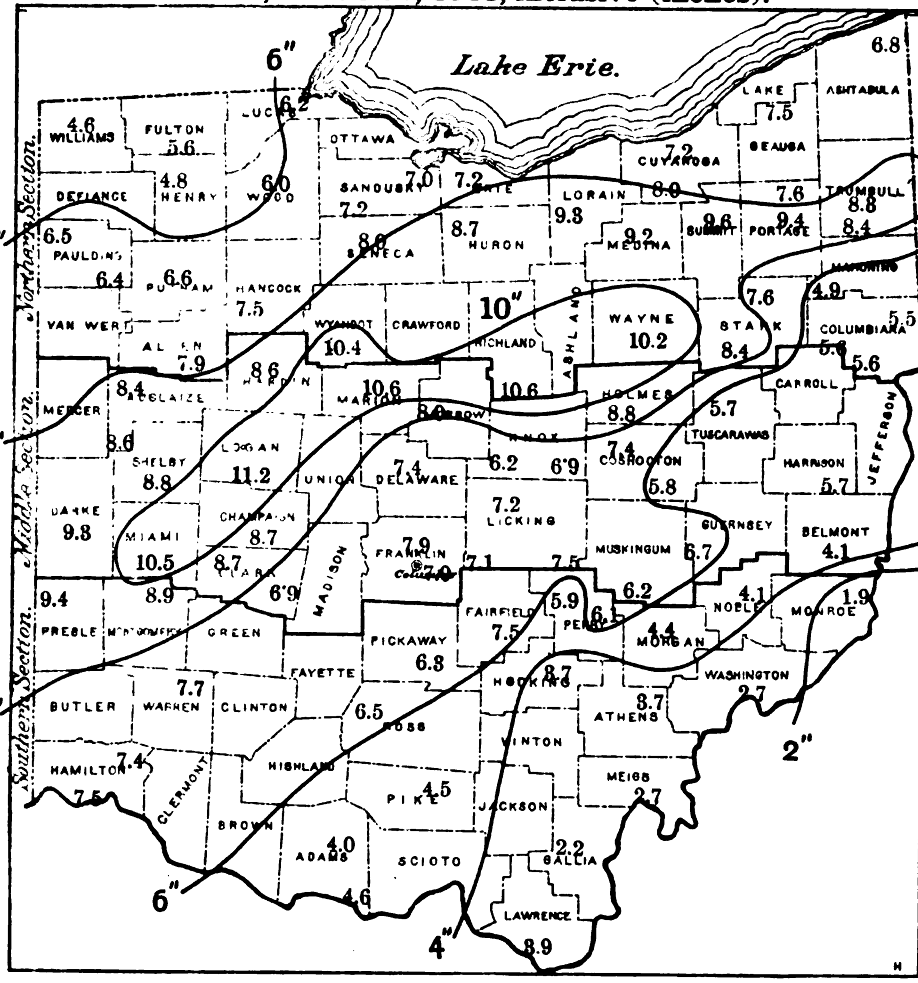


Chart 9, Part 2. Total damage to highways and bridges in flood of March, 1913, as furnished by county commissioners in July, 1913.

PRECIPITATION AND FLOODS IN OHIO, MARCH, 1913.

By J. WARREN SMITH, *Professor of Meteorology.*

The flood of March, 1913, was due to an excessive rain falling upon a surface that was already thoroughly saturated. There was no snow upon the ground, and the surface soil was not frozen, so that the usual winter flood conditions were absent; but the surface soil was very wet, and small streams and depressions were well filled by frequent precipitation during the first part of March.

On Sunday, March 23, rain began to fall in northwestern Ohio at about 8 a. m., and in central districts during the middle of the forenoon. The rainfall during Sunday was about 2 inches in the Maumee and Sandusky watersheds, in northwestern Ohio, and about 0.5 inch in central districts, but was very slight in southern counties. The rain ended by early evening in most of the State.

Rain began to fall again soon after midnight and fell almost continuously through the 24th, 25th, and 26th. By the morning of the 24th the total 24-hour rainfall was about 3 inches in the Sandusky, Maumee, and upper Great Miami River Valleys, but less than 1 inch in the southeastern portions of Ohio.

During the day, Monday, March 24, the fall was heaviest in the upper Great Miami Valley and amounted to 3.7 inches at Piqua, Miami County.

The rainfall for the 24 hours ending the evening of the 24th averaged 1.9 inches in the Scioto Valley above Columbus, 1.9 inches in the Great Miami Valley above Dayton, 2.1 inches in the Little Miami Valley, 1.6 inches in the Sandusky Valley, and 1.3 inches in the Muskingum Valley above Zanesville. The greatest fall reported was 5.6 inches at Piqua.

The total rainfall from Sunday morning up to the evening of Monday the 24th averaged 3.6 inches in the Sandusky watershed, 3.1 inches in the Scioto above Columbus, 2.9 inches in the Great Miami above Dayton, 2.4 inches in the Little Miami, and 1.9 inches in the Muskingum above Zanesville. In Hancock and Wyandot Counties it was over 4 inches, and in Miami County 6.6 inches.

The rainfall was very heavy during Monday night. At Bellefontaine, in Logan County, it was about 4.5 inches; in Richland County, 4 inches; Marion County, 3.6 inches; Shelby County, 3.5 inches; and in Seneca County, 3.3 inches.

The total rainfall up to the morning of the 25th is shown in chart No. 6. The precipitation on that chart is for 48 hours, and it was that rainfall which caused the flood waters in Indiana and western Ohio. Unfortunately not many of the observations are made in the morning, but the above-named chart shows a fall of 9 inches in Miami County, and 7 inches in Marion County, and 7.4 inches in Logan County. The fall was over 6 inches over a large portion of the north-central part of Ohio.

The heaviest rainfall had moved eastward by the 25th, and the Muskingum Valley received more than the western watersheds. At Ashland, Ashland County, the fall from 12.30 p. m., Monday, the 24th, until 12.30 p. m., Tuesday, was 5.96 inches. The rainfall for the 24 hours ending the evening of the 25th was more than 4 inches over a large part of the upper Muskingum watershed, as well as in the central Great Miami Valley and the upper Scioto.

The total rainfall up to the evening of the 25th is indicated in chart No. 7. The total rainfall from the morning of March 23 to the evening of March 27 is given in chart No. 8. It shows that the fall was over 10 inches over a large district.

Table No. 2, page 64, gives the carefully determined average rainfall in each watershed for each 24 hours and for the 5 days. The area of the watershed is shown, as well as the calculated fall of water, in cubic feet per square mile. The Great Miami watershed (total) includes the White Water River in Indiana, where the rainfall was very heavy.

The daily rainfall records will be found in Table No. 2, page 21.

A very careful study of the run-off from the small valleys of the upper Great Miami River is being made by the Morgan Engineering Co., of Dayton, and their computations show that the rainfall over a large district east of Piqua and Troy must have been considerably greater than was recorded at any of the surrounding stations.

OTHER HEAVY RAINFALLS.

The heaviest monthly rainfall in Ohio since the records began in 1854 was in September, 1866. At North Lewisburg and Urbana, Champaign County, the total fall for the month was 15.9 inches, while the average for 20 stations well distributed over the State was 9.7 inches.

The following item relative to the high water of that month is from the twenty-eighth annual report of the Ohio Board of Public Works for 1866:

> Very extensive damage was done at Circleville on September 19. The water was 8 inches higher than in the great flood of 1860, which was then said to be unprecedented in the Scioto River. The water flowed over the high canal bank for almost the entire distance between the lock at the west end of Circleville aqueduct and Foresman's mill, and near the last-named point the banks were entirely swept away. Several breaks occurred in the canal feeder between Columbus and 4-mile lock. Much damage was done to the canals in the Muskingum Valley.

This rain gave the highest water at Dayton previous to March, 1913, but daily records are not available.

A careful tabulation has been made of all of the 24, 48, 72, and 96 hour rainfalls at all of the stations in Ohio from 1883 to date. This table is too long to publish in this report, but it shows that the only time when the rainfall approaches that for March, 1913, in area covered and intensity of fall was in October, 1910. (See Chart No. 3.)

The rainfall for October 5–6, 1910, was 7.5 inches in Butler County; 7.7 inches in Warren County; over 6 inches in Montgomery, Clark, Champaign, and Delaware Counties; and over 5 inches from Hamilton north to Shelby County and east to Richland County. The fall for October 4 to 7, inclusive, 1910, was not so heavy by a third as occurred on March 23 to 26, 1913, and the heaviest rainfall was in the lower portion of the Great Miami Valley instead of the upper watershed as in March, 1913.

RISE OF THE RIVERS.

The streams in the northwestern portion of Ohio began to rise rapidly during the night of the 23d, and by the morning of the 24th the flood stage was passed at Fort Wayne, Ind., and at Upper Sandusky and Tiffin, Ohio.

By noon of the 24th the Great Miami, Little Miami, and the Scioto Rivers had begun to rise at a rapid rate. These rivers continued to rise during the night of the 24th and the morning of the 25th, and in the lower portions until the 26th.

The Muskingum River did not begin to rise rapidly until the night of the 24th, and did not reach its highest stage until the 27th.

The river gauge readings are shown in detail in Tables Nos. 3 and 4, and a further discussion of the rate of rise is given in the story regarding each watershed.

From the figures of Table 2 the total amount of water falling on the several watersheds can be easily determined and the probable run-off calculated. In the Scioto watershed above Columbus the total fall of water from the 23d to 27th, inclusive, amounted to 235,813,912,500 gallons, or 31,441,855,000 cubic feet.

DAMAGE AND LOSS BY THE FLOOD.

The following statement gives the best figures of the loss and damage that it has been possible to collect. In many cases the amounts given are only estimates, but they are conservative ones, and the total loss was undoubtedly far greater than these compilations indicate. (See also Table 5.)

But no tables can tell all the tale; indeed, no pen can recount the story of horror, of suffering, of countless acts of self-sacrifice and heroism. There were many instances of the savings of a lifetime being wiped out in an hour, of priceless pictures, books, and heirlooms washed away or ruined by the water and mud.

Neither do the tables tell of light plants being out of use and cities and villages in darkness for a week or more, of water supplies being cut off, sewage plants out of commission, or farm lands completely destroyed. The whole story is indeed a sad one, and undoubtedly the "Big flood of 1913" will be a reckoning point for many years to come.

There were over 100 municipalities in Ohio affected by the flood. The total population of the cities and towns most affected by the flood was 1,388,000. The total number of lives lost in the flood as near as can be determined was 467. The approximate number of residences flooded was 40,637, and the approximate number of houses destroyed was 2,220.

Total estimated money loss in Ohio.

Damage to public highways and bridges (see Chart No. 9)	$12,031,039
Damage to buildings and personal property	78,072,387
Damage to farm buildings and fences	1,352,000
Damage to farms by soil washing	3,300,000
Damage to farms by driftwood and débris	350,000
Crops destroyed or damaged	1,412,800
Loss of live stock	234,953
Cost of cleaning and repairs to machinery, etc	3,762,100
Damage to railroads, physical plants	6,051,300
Loss to railroads, enforced suspension of business	6,000,000
Damage to interurban electric roads	220,872
Loss to same by suspension of business	173,965
Damage to street and suburban lines	221,383
Loss to same by suspension of business	200,000
Damage to physical plants of telephone lines	110,006
Loss to same by enforced suspension of business	20,113
Damage to lines of Western Union Telegraph Co	150,000
Total	113,662,918

MAUMEE RIVER.

The Maumee watershed covers the northwestern corner of Ohio, northeastern Indiana, and a small portion of southern Michigan. It has a total area of 6,344 square miles, 4,702 of which are in Ohio. It empties into Maumee Bay at the western end of Lake Erie. The main tributaries from the north are the Tiffin and St. Josephs Rivers, and from the south the Blanchard and St. Marys Rivers. The rivers of the southern watershed flow through a district that is extremely flat. The northern watershed is more rolling.

At Montpelier on the St. Josephs River the water was 7 feet higher than has been experienced for some years.

At St. Marys, near the head of the St. Marys River, the water was from 2 to 3 feet higher than before known, but only a small per cent of the city was flooded. There was much uneasiness, however, because of danger from the Grand Reservoir, which is situated about 2 miles west. Many people left their homes in this city, as well as in Celina at the western end of the reservoir, and fled to higher ground. This reservoir has an area of 15,748 acres and is the largest artificial lake in Ohio. It drains only about 93 square miles, but filled very quickly with the

heavy rainfall, and there was considerable washing of the banks. The spillway from this reservoir is at the western end, and the surplus water flows into the Wabash River.

At Wapakoneta on the Auglaize River the water was 3 feet higher than any previous record. The damage was not large.

Findlay is on the Blanchard River, a branch of the Auglaize. The water here was 3 feet higher than during the previous highest flood, on April 1, 1904, and 60 per cent of the city was flooded. There was one death, and 3,000 people were driven out of their homes by the water.

Ottawa is also on the Blanchard River and is in the same flat region. Fully 95 per cent of this city, which has a population of 2,200, was flooded, although in most of the city the current was not swift and little damage was done to buildings.

Lima is on the Ottawa River in central Allen County. Where unobstructed the water was 1.5 feet higher than the former highest record, on April 1, 1904. There was one death and considerable property damage in this city.

Two hundred and sixty-eight houses were flooded at Defiance and 150 at Napoleon, both on the Maumee River, and there was one death at Napoleon.

The damage along the smaller streams that empty into Lake Erie was not generally large outside of the injury to railroads and bridges. The Portage River at Bowling Green was 3 feet higher than any previous record. In Lorain County a railroad engine broke through a weakened trestle and the crew of three men was drowned. In Cleveland the lowlands along the Cuyahoga River were overflowed and a large amount of lumber and other light material was carried downstream and into the lake. The wooden wharves along the river banks and a large amount of freight in cars standing in the railroad yards were damaged. Damage was done to bridges by the breaking away of steamers from their moorings.

A good deal of damage was done at Akron, Summit County, on the Little Cuyahoga River, by the breaking of the banks of the largest of a string of artificial lakes known as the Portage Lakes. It is called the East Reservoir, and the bank was cut where the feeder from the Tuscarawas River enters. The power equipment and storerooms of the Goodyear tire and rubber plant were flooded, causing a loss estimated at from $50,000 to $100,000; one of the city playgrounds was damaged to the extent of $12,000; bridges were carried away; and 15 to 30 houses were demolished.

At Akron, as well as at many other points along the watershed between Lake Erie and the Ohio River drainage areas, the unusual spectacle was presented of large damage from flood at the crest of the watershed. At Bellevue, at the junction of Sandusky and Huron Counties, the flood did not recede for nearly five weeks, the first floors of many of the houses being flooded for this period. This village, with a population of about 4,149, is not located on a stream, but the surface water is usually drained into natural "sinks" or else drilled holes. Because of the excessive rainfall, the ground water was rapidly raised and the "sinks" which take the water in under ordinary conditions became springs.

SANDUSKY RIVER.

The Sandusky River rises in the western portion of Richland County, flows west through Crawford and into Wyandot County, then north through Seneca and Sandusky Counties, and empties into the west end of Sandusky Bay in southern Lake Erie. The river is 115 miles long and drains 1,554 square miles. Its headwaters are 709 feet above the mouth. The valley is small, having a depth of from 20 to 25 feet and an average width of one-fourth mile or less. There are quite a number of dams along the main stream, the largest being the Ballville Dam, 2 miles above Fremont.

The heavy rainfall caused a rapid rise of all the small streams in this valley, and on the morning of the 24th the river at Upper Sandusky was 3.8 feet above the flood stage and was just at flood stage at Tiffin. It rose steadily and rapidly at Upper Sandusky during the next 24 hours and reached 19 feet at 9 a. m. March 25. This was 6 feet above the flood stage, and 3

feet higher than occurred February 3, 1883, and 4 feet higher than on March 4, 1847, the previous high-water records. Inasmuch as the river is some 25 feet or more below the general level, very little damage was done either in Wyandot or Crawford Counties.

At Tiffin, Seneca County, the flood was much more serious. The river flows through the center of the city from southwest to northeast, and a fair-sized branch comes in from the southeast. The buildings encroach very decidedly upon the stream channel, and this is very narrow and crooked. It is crossed by six bridges, none of which was high enough or wide enough to prevent damming.

The river was at flood stage (7 feet) at Tiffin at 7 a. m. March 24 and had risen to 7.8 feet at 1 p. m. At 7 a. m. the 25th the gage was 12.5 feet, and at 11 a. m. it was 14 feet, and the bridges and streets near them were impassable. At 1.40 p. m. the first bridge went out; and, as the current is very swift through the city, the other bridges and buildings nearest the channel were carried away in rapid succession. The height of the water at the river gage was 19.4 feet at 6 a. m. March 26, or 8 feet higher than ever before recorded. At the Hubach brewery it was 28.9 feet, or 10.3 feet higher than the previous record, and at the waterworks 9 feet above the highest before known.

The observer, Prof. T. H. Sonnedecker, has made some investigations and concludes that this was the greatest flood in that valley since it has been settled by the white man and probably the greatest in this geological era.

At Fremont the river passed the flood stage, 10 feet, at about 9 a. m. of the 24th. At 7 p. m. it was 12.4 feet; at 7 a. m. of the 25th, 13.5; at 3 p. m., 17.5; and by noon of the 26th it had reached 21.5 feet, or 3.7 feet above the record of February, 1884. It remained practically stationary until the following morning. The river gage is on the downstream side of the bridge, and it was 1 foot higher above than below the bridge.

About 35 per cent of the city was flooded, which includes a large proportion of the business district. The loss to merchandise stock and buildings was estimated at $262,000. The loss on the Ballville Dam was $85,000. Three men were drowned at Fremont.

MAHONING RIVER.

Numerous power and water-supply dams on the Mahoning River makes this river a series of pools and riffles from its source to the Pennsylvania line, greatly affecting the run-off of the stream.

At Warren, in Trumbull County, the river was 4.2 feet higher than before recorded. Two persons were drowned and 150 houses were flooded. The highest water was at 6 p. m. March 26.

At Garrettsville, Portage County, the water was 1.5 feet higher than any previous record.

Niles, Trumbull County, the river was 6.8 feet higher than in January, 1904, the previous high water. From 10.15 p. m., March 24, until 8.15 a. m., March 25, the water rose at an average rate of 6 inches per hour.

At Youngstown, Mahoning County, the highest water was at 11 p. m. March 26, when it reached 22.9 feet, or 7.1 feet higher than the previous record, January 21, 1904.

HOCKING RIVER.

The rainfall was not particularly heavy in southeastern Ohio and the flood was not so serious in the Hocking Valley as elsewhere. At Logan, Hocking County, the river was not so high by 1.5 feet as was recorded in 1884.

WHITE WATER RIVER, IND.

The highest stages for this stream and its tributaries ever known were reported during the flood period March 23–27, 1913. The rainfall in this valley as reported by cooperative observers of the Weather Bureau for this period was as follows: Cambridge City, 9.38 inches;

Connersville, 9.98 inches; Richmond, 11.15 inches. On March 25, Cambridge City recorded 5.70 inches; Connersville, 5.67 inches. On March 24, Richmond reported 5.30 inches and on the 25th 4.17 inches, making a total of 9.47 inches for the 48 hours. No snow was on the ground to augment the stream flow, but the ground was well soaked by previous rains when the heavy downpours occurred and the run-off was quite rapid. Perhaps it was equal to what it would have been had the ground been frozen.

The county commissioners of Union, Henry, Fayette, Wayne, and Randolph Counties report a total loss of $161,100 in damage to county and municipal bridges and a loss of $67,500 in damage to public highways. This makes a total loss of $228,600 in damage to public highways and bridges.

Interurban electric lines operating in this valley report a loss of approximately $35,000 to their lines, bridges, and rolling stock and about $20,000 loss in business due to enforced suspension.

The correspondent at Cambridge City reports the loss of two lives due to the flood. The Red Cross Society reports 15 deaths at Brookville, Franklin County.

THE GREAT MIAMI RIVER.

The drainage basin of the Great Miami River lies in southwestern Ohio and southeastern Indiana and has an area of approximately 5,400 square miles. One-third of the total area is in Indiana. The river is formed in Logan County by two small streams rising in Auglaize and Hardin Counties. It flows in a southwesterly direction and joins the Ohio River at the Indiana State line. The length of the river is 140 miles. The main tributaries are the Stillwater River from the west and the Mad River from the east, both entering the Great Miami just above Dayton.

The valleys above Dayton are narrow and comparatively shallow, while below Dayton the valley is broad and open. The average fall of the river is 4.1 feet per mile and is steepest in the upper part, especially in the Mad River drainage area.

The Lewiston Reservoir is in Logan County and is often designated as the source of the Great Miami. It has an area of about 6,134 acres and drains a watershed of 100 square miles.

The Loramie Reservoir is situated in the western portion of Shelby County and feeds into the Great Miami between Sidney and Piqua. It has an area of 1,900 acres and drains 70 square miles.

Both of these reservoirs were soon filled at the time of the heavy rainfall and there was grave danger that the banks would give way. There was no serious break in either one, however, and on the other hand they did very little to minimize the flood conditions.

Sidney is the first large town on the upper Miami. It is located in Shelby County and has a population of nearly 7,000. Only about 6 per cent of the city was flooded by the high water, and no lives were lost. But three residences were destroyed, although 230 were in the flooded district. The water was the highest at about 9 a. m. March 25, when it was 4 to 6 feet higher than before recorded. The damage to buildings and personal property is given as $35,000.

The damage was much more at Piqua than at Sidney. Fully 50 per cent of Piqua was flooded, and 44 lives were lost. The number of residences flooded was 2,000, and 100 or more were destroyed. The river gage at Piqua was at 8.7 feet on the morning of the 24th, and the water had risen only to 11 feet at 5 p. m. It rose more rapidly after that hour and reached the flood stage of 14 feet at 9 p. m. The rise from that hour until 10 a. m. on the 25th was 10 feet. The river was about stationary at 24 feet until 2 p. m.; then fell steadily. By the 27th it had fallen to the flood stage. About 2,000 people were rendered homeless at Piqua. During the night of the 24th the water broke through the levee that protected the portion of the city east of the Miami and Erie Canal and also flooded East Piqua. Later the water came down through the main portion of the city. The water was 6 feet deep in some of the business districts, and the flood damage was very great.

FIG. 9.—FOURTH AND MAIN STREETS, DAYTON, OHIO. FLOOD OF MARCH, 1913.

Looking north on Main Street, water about 10 feet deep. Taken shortly before dark Tuesday, March 25, 1913. (Copyright by Smith Bros., Dayton, Ohio.)

FIG. 10.—STEELE HIGH SCHOOL BUILDING, DAYTON, OHIO.

Showing destruction due to undermining foundation by water.

Troy is the next town of moderate size below Piqua. It has a population of over 6,000 and covers about 2 square miles. Fully 75 per cent of the city was flooded. Water affected nearly 1,000 houses, and 50 were washed away. The highest water was about noon March 25. Sixteen lives were lost. The loss at Troy was, to business houses. $35.000; factories, $150,000; residences and personal property, $175,000.

Springfield is a city of nearly 50,000 population and is situated on the Mad River in central Clark County, 25 miles above Dayton. A moderate amount of damage was done in the city, as most of it is well above flood waters, and only one life was lost.

Dayton is in Montgomery County, 33 miles below Piqua and 77 miles above the Ohio River. The drainage area above the city is 2,558 square miles. The river is 600 feet wide at average low water. The central portion of the city is located on the flood plain of the river, which at this point is about 3½ miles wide. Approximately 50 per cent of the city is built on this flood plain. The following report is made by Mr. H. F. Alps, local forecaster at Dayton:

REPORT OF FLOOD AT DAYTON, OHIO, MARCH 25, 1913.

The most destructive flood in the history of Dayton occurred on Tuesday morning, March 25, 1913, following about 36 hours of unprecedented rainfall over the Great Miami River watershed. The center of the city was submerged to a depth of 9 feet, and in many of the lower sections the measured depth was 20 to 21 feet. It is known that 96 persons were drowned, and that the losses totaled about $75,000,000. Before the people

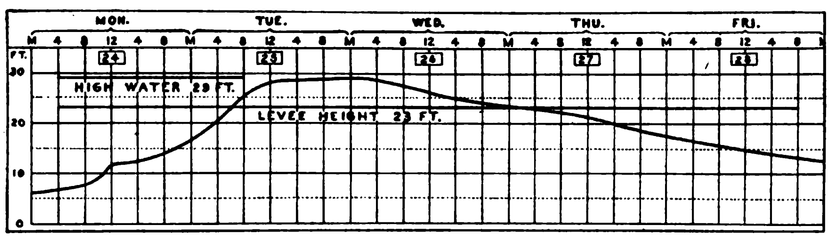


DIAGRAM III.—Hydrograph, Great Miami at Dayton, Ohio, March 23–29, 1913.

could realize the city was going to be overwhelmed, the flood wave had swept over the lower portions and was rapidly approaching the business center. An hour after the water started over the levees it was impossible to cross from the residence sections of the north and west into the business district, and in less than five hours after the water overtopped the lowest points in the levees the entire business section was covered to a depth of several feet. The business district and large portions of the residence sections are located in the lowlands. This low, flat area, covering about 7.5 square miles, was all submerged during the flood. It is approximately 4 miles in length and 2 miles in width. Adjacent to this level flat are hills with varying slopes having an area of about 9 square miles and used chiefly for residence purposes. The Mad River, Stillwater River, and Wolf Creek discharge into the Miami River within the city limits. The levees were constructed to safeguard against a stage of 23 feet, which is 6 feet below the crest of the flood of March 25.

On Sunday morning, March 23, the reading of the river gage was only 3 feet. It was 7 feet on the morning of the 24th, and the rise during the day was moderate and fairly steady. At 12 o'clock noon the gage reading was 11.6 feet; at 4 p. m. it was 12.2 feet; at 8 p. m. it was 14.2 feet; at 10 p. m. it was 15.3 feet; and at 12 midnight it was 16.4 feet. About 2 a. m. of the 25th the water had reached the flood stage, or 18 feet, and the rise during the following eight or nine hours was exceedingly rapid. The water started over the levee in the north portion of the city about 5 a. m., and by 9.30 a. m. water several feet in depth with a dangerously swift current was flowing through the heart of the city. The flood crest was nearly reached by 11 a. m. The rise then became very slow, the stage being 28.3 feet about 3 p. m. and reaching a maximum of 29 feet about midnight. The water receded slowly, the total fall to 4.30 a. m. of the 26th being 0.7 foot. At 3 p. m. the water was 4 feet below the crest, and the fall was fairly steady afterwards, as is shown graphically by the curve which is plotted from the several special measurements made during the flood. (See Diagram III.) The water lowered to the flood stage by about 10 p. m. of the 27th, and it had fallen below the streets in the business section on the morning of the 28th, so that many people were permitted by the military authorities to enter the city and start the work of rehabilitation.

RAINFALL.

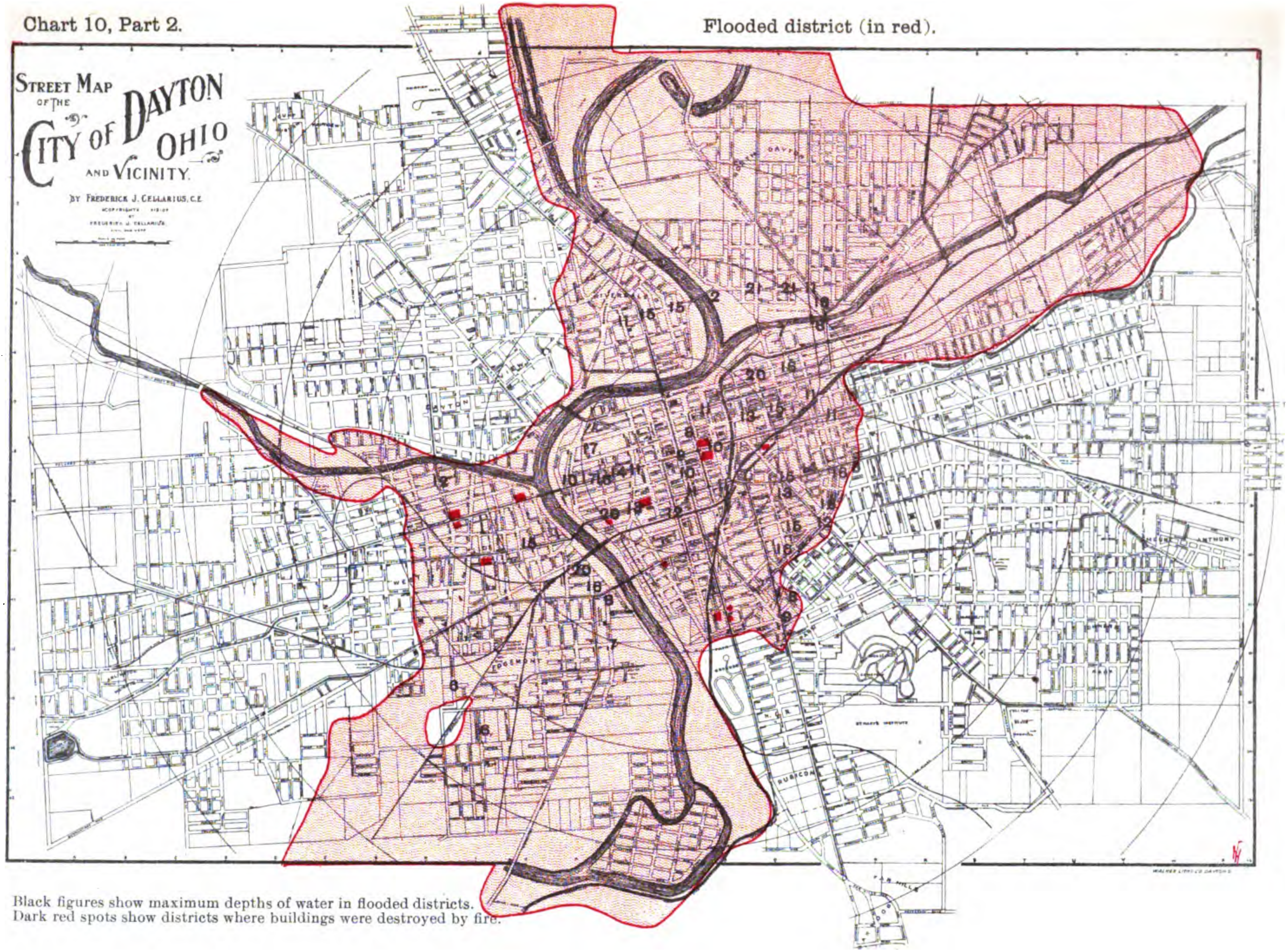
Rainfall contributory to the flood started on Sunday, March 23. On that date there was 0.48 inch at Dayton, which fell from 7.42 a. m. to 10.56 a. m., a brisk shower occurring between

8 and 9 a. m. Then there was no rain of any consequence until 7 a. m. of the 24th, when rain began and continued until after midnight of the 25th. During this period of rain there were four heavy showers at Dayton. From 7.10 a. m. to 7.38 a. m. of the 24th, 0.52 inch fell; from 3.21 p. m. to 3.47 p. m. of the 24th, 0.54 inch fell: nearly a half inch fell between 6 p. m. and 7 p. m. of the same date, and 0.58 inch fell between 2 a. m. and 3 a. m. of the 25th. From the beginning of the rain, at 7 a. m. of the 24th, to about 4.30 p. m. of the 25th, when the river had practically reached its crest, the total amount of the rainfall, as shown by the automatic record at the local office, was 5.17 inches. The amount falling during about the same period at the cooperative station in the edge of the city, where the rain gage has a more suitable exposure, was 6.19 inches; 4.40 inches of rain fell during the 24 hours ending about 7 a. m. of the 25th, and the rainfall during the remainder of the day was comparatively light. The rainfall at the cooperative station, measured by Mrs. Edith E. L. Boyer, an excellent observer, was about 15 per cent greater than the amounts measured at the local office. If 15 per cent is added to the 24-hour fall of 4.40 inches, the amount is raised to about 5 inches. It is interesting to note that about one-half of the 24-hour fall of 4.40 inches was recorded in the four showers, which altogether covered about 2 hours. The rainfall at Piqua, about 33 miles north of Dayton, on the Miami River, was very heavy. The amount measured there for the 17 hours beginning at 7 a. m. of the 24th and ending at midnight was 5.43 inches.

An examination of the rainfall table (see page 54) will show that heavy amounts were recorded on the 24th and 25th at all stations above Dayton, in the drainage area of the Miami River and its tributaries. Judging from the available records of rainfall and the time the high water reached Dayton, it is believed the average 24-hour rainfall for the entire basin above Dayton would be about 5 inches had measurements been made at the several stations for the 24 hours ending about 7 a. m. of the 25th. The average in the basin for the entire period of rainfall, beginning on the 21st and ending on the 27th, was about 8.80 inches. The rainfall was not unusually heavy for short periods of time. On May 12, 1886, when some damage was done by floods at Dayton, 4.50 inches of rain fell in about two hours. However, the rainfall during the recent flood was the greatest on record falling over the entire basin in that period of time. It was also the greatest amount that has fallen in the basin during a period of 24 hours. The rainfall approaching more nearly the amounts of March, 1913, than any other on record was on October 5–6, 1910, when the average for the two days in the basin above Dayton was about 5.50 inches. At that time the river only reached 16.1 feet, but the soil was not saturated to begin with, as was the case in March, 1913. The most destructive flood known before the recent one was on September 17, 1866, but the conditions then were so different from those prevailing now that no comparison can be made. The cultivation of the soil and the drainage systems which are now in use provide for the rapid flow of the water into the channels. The investigation in the Miami Basin, which has been conducted by noted engineers employed by the Dayton citizens' relief committee, has disclosed the fact that the maximum discharge of the river at Dayton on March 25 was approximately 250,000 cubic feet per second. As the drainage basin of the river is about 2,500 square miles, this would give the unusually large average maximum discharge in the basin of 100 cubic feet per second per square mile. The maximum capacity of the channel at the time of the flood is figured at 100,000 second-feet. This would leave 150,000 second-feet flowing through the city outside the river banks.

The flood converted the city into a river about 2 miles wide, with a current which was generally too swift to operate rowboats. (See chart No. 10, overflowed area in Dayton, Ohio, p. 51.) People were marooned in the second stories throughout the flooded districts, and in many cases it was necessary to find refuge in the attic or upon the roof. There many of them remained from two to three days without food and water. The fires which burned business blocks and other buildings added to the suffering. Rowboats were in constant use where it was possible to reach the people. The local office began sending out flood warnings at 12.30 p. m. of the 24th, first into the most exposed places and later to other districts. The warnings were continued until about midnight, and it is believed they resulted in the saving of many lives.

Chart 10, Part 2. Flooded district (in red).



Black figures show maximum depths of water in flooded districts.
Dark red spots show districts where buildings were destroyed by fire.

A number of families moved from low places on the evening of the 24th, and others were keeping watch on the river. About 2.30 a. m. of the 25th, when the rise in the river was increasing and the rainfall was alarmingly heavy, whistles were blown and bells were rung to warn the people of the danger. About 3 a. m. messengers started through the lower residence sections asking the people to leave their homes, and this was continued until the water flooded the streets. The loss of life was exceedingly small when compared with the severity of the flood.

Portable structures and the lighter frame houses were swept away, and many foundations of substantial buildings were undermined. Several miles of asphalt pavement were ripped from the streets and broken to pieces. It would be difficult to describe with any degree of accuracy the enormous financial losses resulting from the flood. The most authentic data as to the losses sustained were secured by the Dayton citizens' relief committee after a careful investigation of all interests and personal inspection of 2,164 residences in the flooded zone. This report is as follows:

Loss to public property	$2,068,100
Loss to public utilities, steam, street, and interurban, gas and electric lighting companies, telephone and telegraph companies	5,884,573
Loss to public utilities, account of loss of business	838,631
Fire loss over insurance	975,236
Damage to buildings	15,200,000
Damage to household furniture and furnishings	9,440,000
Loss to merchants on stock and fixtures	18,000,000
Loss on live stock, automobiles, and vehicles	1,000,000
Factory losses:	
Wages	4,045,000
Stock and machinery	8,747,500
Business loss	1,900,000
Loss on contracts, rents, etc	3,450,000
Pianos in homes	800,000
Leaf tobacco in warehouses	900,000
Total	73,249,040

DAYTON FLOODS IN PAST YEARS.

The first severe flood that we have record of at Dayton was in March, 1805, which is said to have been due to the thawing of deep snows and the occurrence of heavy rains in the headwaters of the Miami and Mad Rivers. During that flood the water covered the whole town, except a portion of the business center. According to local history, the people seriously considered the proposition of moving the town from the lower flat to the higher ground in the east portion. The next flood of importance was in 1814, when the water was said to have been deep enough at the corner of First Street and the canal to swim a horse. The third notable flood occurred on January 8, 1828, when a warehouse was washed away from the head of Wilkinson Street and the entire southern part of town was submerged. Another flood visited Dayton in February, 1832. The high-water mark at that time equaled the high-water mark of the flood in 1828. A flood occurred on January 2, 1847, which covered everything except an island in the center of town. The water came up to Fifth Street, but it was not so high as the flood of 1805. The loss was $5,000. The most severe flood of record, with the exception of the flood of March 25, 1913, occurred on September 17, 1866, when, it is stated, heavy rains for three days caused a rise in the river which overflowed practically the entire town. The water was 1 foot deep on the floor of the Beckel House and 4 inches deep on the floor of the Phillips Hotel. The loss was $250,000. As the town then had only about 15,000 inhabitants, this loss was comparatively great. The next flood was on February 3, 4, and 5, 1883. The danger at that time was increased by large ice gorges which formed in the stream. The water came up as high as the flood of 1847, but it was about 2 feet below the high-water mark of 1866. Wolf Creek

rose to an unprecedented height, and the western and southern parts of the city were under water. On May 12, 1866, another flood occurred. At that time 4.50 inches of rain fell at Dayton in about two hours. Wolf Creek was high, and most of the damage was done by the overflow on the west side and the back water in the south portion. In March, 1897, and March, 1898, severe floods occurred, the latter being the most destructive. Much damage was done in North Dayton and Riverdale by these floods. During the flood of 1898 work was done on the levee to save the business section, and it is stated that a rise of 6 inches more would have flooded that district.

Rainfall over the Great Miami River watershed above Dayton on Mar. 24 and 25, 1913, when the heaviest rainfall occurred.

Stations.	Mar. 24.	Mar. 25.	Stations.	Mar. 24.	Mar. 25.
	Inches.	*Inches.*		*Inches.*	*Inches.*
Bellefontaine	1.52	5.61	Sidney	1.84	3.96
Dayton	2.95	2.27	Springfield	2.01	3.57
Dayton (cooperative)	2.91	3.28	Urbana	2.13	3.12
Greenville	1.77	4.45	Wapakoneta	1.66	3.29
New Bremen	1.80	3.22			
Piqua	5.50	[1] 1.71	Average	2.36	3.32
Plattsburg	1.75	2.01			

[1] To midnight of the 24th.

Rainfall over the Great Miami watershed above Dayton for the period from Oct. 4 to 7, 1910.

Stations.	Oct. 3.	Oct. 4.	Oct. 5.	Oct. 6.	Oct. 7.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Dayton		0.06	3.82	2.78	
Bellefontaine		.07	2.65	2.98	0.10
Greenville		.70	2.50	1.94	
Kenton	0.04	.14	2.27	2.86	.10
New Bremen		.89	1.87	2.24	
Piqua			2.80	1.84	2.20
Plattsburg		T.	3.00	3.72	
Sidney		.27	3.25	2.46	
Urbana			2.80	3.50	.10
Average		.24	2.77	2.70	.28

NOTE.—On Oct. 7, 1910, the river reached 16.1 feet.

Miamisburg is below Dayton. Only a small portion of the village was affected by the flood; but 1 life was lost and 16 buildings wrecked.

Franklin is the next town down the river, and the part of the residence section that is on the west bank of the river was flooded, and much damage was done. Fourteen buildings were washed away and 7 people drowned.

Middletown is in northeastern Butler County and has a population of about 15,000. About 25 per cent of the city was flooded, including the business section and the better residence portion. Six people were drowned and 41 houses destroyed.

The city of Hamilton is in south-central Butler County and has a population of 39,000. It is built on both sides of the Great Miami River, with the main business and residential portions on the east bank. The land is very flat, and the main built-up portion of the city lies in the level valley of the river.

The official river gage at Hamilton showed 4.8 feet of water in the river on the morning of the 24th. By noon it had risen 4 feet, and at 5 p. m. the reading was 12 feet. At 6 a. m., March 25, the reading was 18.8 feet, at 5 p. m. it was 25 feet, and at 3 a. m. of the 26th it had

reached its highest point of 34.6 feet. The observer, Mr. Earl W. Stout, reports that by noon of the 25th the water was 2½ feet over the Main Street Bridge and that the bridge was destroyed at 12.25 p. m. Later in the day the railroad bridges went out, thus leaving no connection with the two sections of the city. By the night of the 25th the water covered all streets on the east side of the river and four streets running north and south on the west side.

The water was not high enough in most of the business section to damage goods on the first floor, but in some of the residence districts it was from 10 to 18 feet in depth.

Forty-six per cent of the city was flooded, 335 houses were destroyed, and 98 lives were lost. The following statement of loss has been furnished by the secretary of the citizens' relief committee, dated May 16, 1913:

Loss of life, probably	150
Bodies recovered to date	92
The city of Hamilton	$404, 300
Public schools	2, 500
County public works	667, 000
Coke Otto suburb	60, 000
Public communication utilities	105, 500
Farm lands	425, 000
Railway, steam and electric	585, 000
Factory losses	2, 799, 218
Residence lands	134, 955
Residence buildings	1, 476, 480
Household goods	1, 565, 770
Mercantile stock	1, 453, 090
Live stock	13, 988
Public library	21, 000
Total loss	9, 723, 801

The above estimate does not take account of depreciation in value of real estate of the city of Hamilton, which depreciation will be a net loss unless the city can be proteced from the danger of future inundation. The consensus of opinion among all real estate men is that this depreciation amounts to about 33⅓ per cent. The total taxable value of the real estate of the city of Hamilton was $31,838,420. The loss through depreciation, based on the theory that flood protection is not to be provided, amounts to $10,612,806. The aggregate losses, direct and indirect, will therefore be $20,336,607. It is our opinion that real estate values will quickly recover when adequate protective works have been provided. (C. R. Green, secretary.)

THE LITTLE MIAMI.

The Little Miami watershed has a drainage area of about 1,709 square miles. The river rises in southern Clarke County, flows southwesterly near the western edge of the watershed, and empties into the Ohio River just above Cincinnati. Its principal tributaries all come from the east. The grade is steep in the upper part of the river; in the lower part the valley is narrow and the adjacent bluffs comparatively high.

At Oregonia, in Warren County, the Weather Bureau river gage showed 7 feet on the 24th and 18 feet on the 25th. It reached 21.1 feet at about 11 p. m. of the 25th. Water was in every house in the small village, and considerable damage resulted.

Another river gage is located at Kings Mills, in southern Warren County. The river was only 3.3 feet on the morning of the 24th. It had risen to 13.8 feet at 3 p. m., to 17.8 feet at 7 a. m., March 25, 22 feet at 2 p. m., and 33.7 feet by the morning of the 26th. This was 6.5 feet higher than during the flood of March, 1897. The observer reports that the river rose steadily on the 25th till about 4.30 p. m., when it came to a stand and started falling. Soon after 5 p. m. the river began rising with great rapidity, and from 6 to 10 p. m. the rise was so rapid that little could be done to save property. The town of Kings Mills is located on the high bluff far above the river, but the mills of a large cartridge and powder factory are down in the narrow valley and sustained considerable damage.

Morrow is in the narrow valley at the mouth of a large eastern branch called Todds Fork. The population is less than 1,000 in number, but practically all of the residence and business section of the town was flooded. The water was from 7 to 10 feet deep in the stores on Main Street and much damage was done to the goods. As the current was at no time very strong the buildings were not seriously damaged.

South Lebanon, with a population of 670, suffered a good deal of damage. The valley here is about three-fourths mile wide, with high hills closing in and making the valley much narrower below the village. Practically the entire settled portion of the town was under water, the depth in some of the business streets being fully 25 feet. There is quite a fall through the town and a number of houses were wrecked by the rapid current. All stock in stores and much furniture was destroyed.

Loveland, farther down the valley, has a population of 1,476. The entire business district was flooded to the depth of 5 to 10 feet, and about 25 per cent of the residential area was affected by the water.

SCIOTO RIVER.

The watershed of the Scioto River covers 6,301 square miles. It rises in the eastern portion of Auglaize County and empties into the Ohio River at Portsmouth. The river is 190 miles in length. and has an average fall from source to mouth of 2.6 feet per mile. The principal tributaries are the Little Scioto, Olentangy, Big Walnut, Big Darby Rivers, and Deer and Paint Creeks.

The rainfall was so heavy that damage was done on all of the small streams which go to make up the Scioto River, Kenton, Larue, Marysville, and Marion all suffered much damage because of the flooding of the residences.

The first point on the Scioto River at which a river gage station is located is Prospect, in southern Marion County. This place has a population of about 900 and 75 per cent of the town was flooded. The water was 5 feet deep in the main street. No lives were lost there and no houses were destroyed. The water was 8.5 feet there at 3.30 p. m. March 24, the river having risen 3 feet at that time. It rose to 20 feet on the 26th, reaching 4.5 feet higher than during the flood in 1904.

The first station on the Olentangy River is at Delaware, Delaware County. The river there was at 5.5 feet on the morning of the 23d and the same on the 24th. It began to rise during the forenoon of the 24th, and by 1.30 p. m. was 8.5 feet. It continued to rise with remarkable rapidity during the afternoon. At 10 p. m. the gage showed 13.8 feet; 11 p. m., 14.5 feet; midnight, 14.9 feet; 1 a. m., 16.8 feet; and at 2 a. m. the 25th it was 18.2 feet. It was not possible to reach the gage after 2 a. m., and by morning the bridge on which the gage was set was washed away. Later levelings, however, show that the water reached 27.5 feet at noon on the 25th, or 11.2 feet higher than the highest before recorded, on April 1, 1904.

The river bed at Delaware has been steadily narrowed by bridges, railroad fills, and fills for manufacturing sites, so that it is 180 feet narrower than it was in 1870. In the southern part of the city a high railroad embankment crosses the valley, and the special river observer reports that the water was from 6 to 10 feet higher above the bridge than below it.

Only about 12 per cent of the city was flooded, but the water came in the night and rose so rapidly that there were 18 deaths from the flood. Twenty-three homes were destroyed, 34 were partially wrecked, and business firms suffered a severe loss. All of the bridges across the river were carried away.

Four and one-half miles above the confluence of the Scioto and Olentangy Rivers at the northern edge of the city of Columbus a large concrete dam has been constructed for water-storage purposes. This reservoir has a capacity of 230,000,000 cubic feet, and the watershed area above the dam is 1,032 square miles. This so-called "storage dam" is slightly over 1,000 feet in length and consists of two abutment sections, one at each end, and an overflow section between. The overflow section is 500 feet in length, and was designed to discharge a maximum

rainfall of 6 inches on the drainage area, flowing off in 24 hours, or about 166,500 cubic feet per second.

The gage at the storage dam showed 1.8 feet of water running over the overflow section at 7 a. m. March 24. It rose 1 foot during the next 4 hours. The water rose 1 foot from 2 to 4 p. m. on the 24th and 1 foot from 9 to 10 a. m. on the 25th. It reached its highest point of 12.8 feet at 2.30 p. m. on the 25th.

Columbus is in Franklin County, at the confluence of the Scioto and Olentangy Rivers. The main portion of the city is on the east bank, from 50 to 100 feet above the river. The Scioto River flows in from the north and strikes the city limits at the northwest corner of the western extension of the city. It flows easterly for about 2 miles, then southerly in a winding course through the city. The Olentangy River comes from the north along the western border of the northern extension of the city and unites with the Scioto just before it makes the southerly bend. The total area of that part of the city west of the Scioto River is 4.37 square miles, and 2.7 square miles of this is in the low level flood plan within the bend. The elevation is from 2 to 18 feet above the low-water stage.

This plain is protected by levees on the southern and western bank of the Scioto River, extending a distance of about 7 miles. It is about 2.5 miles from east to west and 1 mile from north to south. The northern portion of this district is given over to railroad yards and there are some factories and business houses, but most of the area was covered with residences. At the beginning of the flood week the population in this section was about 22,500. The river was crossed by 15 bridges within the city limits.

The Weather Bureau river gage is located on the abutment of the most southern bridge after the river has made its long curve through the city. On March 23, 1898, the river was up to 21.3 feet on this gage; the west side levees were overtopped in places and considerable damage resulted. After this flood the levees were strengthened and raised 6 feet throughout the whole distance of 7 miles. The estimated discharge of the two rivers during this flood was 75,000 second-feet, or 47.9 second-feet per square mile of watershed area. It was assumed that the addition of 6 feet to the levees would furnish ample protection against future floods. About one-half of the levee, or that part along the southern bank of the Scioto where it makes the easterly curve, has been occupied by railroad tracks in daily use. Within the last few years the railroad tracks crossing this low plain have been raised to eliminate the grade crossings. The Pennsylvania line parallels the river running from west to east and is a short distance south of the levees, the Baltimore & Ohio track runs across the western portion of the district from southwest to northeast, and two other roads cross it from north to south near the eastern limit. These road embankments are pierced by numerous subways at the street intersections, and it was the rush of water through these subways that caused the greatest destruction of buildings and the greatest loss of life.

The flood stage in Columbus is 17 feet on the gage, when the water begins to flood buildings and low streets on the east side of the river where not protected by levees. The river was 6.2 feet at Columbus on the morning of March 24. It rose steadily through the day and was 13.8 feet by 4 p. m. It passed the flood stage soon after 9 p. m., and by daylight of the 25th had passed the 1898 record. It continued to rise slowly at the gage until it reached 22.9 feet at 11 a. m., stood nearly stationary for an hour, and then fell slowly. It stayed above the flood stage until about noon of the 28th.

These figures show that the water at the Weather Bureau gage was only 1.6 feet higher than in 1898, although a 6-foot higher levee had been overtopped and washed out. The fact is that the water was held back by the bridges that cross it within the city limits and the river was from 6 to 7 feet higher above the confluence of the two streams than in 1898. There were eight bridges between the mouth of the Olentangy River and the Mound Street Bridge, where the gage is located. The narrowest was the Broad Street Bridge, just after the turn is made southward, which had an opening only 290 feet wide at right angles to the thread of the current.

Mr. Julian Griggs, former city engineer of Columbus, states that when the storage dam showed a head of 10 feet passing over it at 8 a. m. on the 25th it was carrying the river channel capacity of 63,246 second-feet, computing by the Francis formula with 4 as a constant for a round-topped weir. At its crest the storage dam was passing 46 per cent more than the channel capacity and there was more than the channel capacity going over the dam until 10 a. m., March 26.

The effect of the flood was felt first along the east side of the Scioto and along the Olentangy from the northern limit of the city southward to the Scioto.

The water reached the top of the levee and began to flow over into the west side district at 9.25 a. m., March 25. In a short time the embankment had been overtopped at a number of places and the water poured over the southern bank of the Scioto above the Olentangy into a basin about 1 mile long and one-fourth mile wide between the river levees and the railroad embankment. The water then passed through the three main subways under this elevated track with a tremendous scouring effect. There were six gaps in the levees aggregating in length 3,300 feet.

At the crossing of the Little Miami Railroad which parallels the river and the Baltimore & Ohio Railroad which crosses the western part of the district, 100 feet of the embankment was washed out, and at one of the subways one of the abutments was washed out and the embankment behind it for a distance of 150 feet. Buildings that were in line with the currents through these breaks were completely destroyed.

After passing the western part of the Little Miami Railroad the water piled up west of the Baltimore & Ohio tracks, rising in a few minutes to a depth of 17 feet. This carried the water over the second-story floors in a populous and desirable residence district, either driving the inhabitants to the attics or to the roofs.

The water rushed through subways of the Baltimore & Ohio and meeting other currents flowing southward on the east side of the track they formed whirlpools and gave a scouring effect that no buildings could withstand. It was in this vicinity that the greatest damage was done to residences and the greatest loss of life occurred. Two streets, Glenwood and Central Avenues, were closely built up with substantial frame houses, but after the flood practically every house for a distance of four squares was gone. Only fragments of foundations were left where before there was a happy and prosperous neighborhood. One house from Central Avenue was found 4 miles below the city. This damage was done during the evening and night of the 25th, fully 12 hours after the levees were overtopped. These people had been warned in ample season to have escaped to higher ground, but no one realized that this district, protected as it was by a high railroad embankment, would get more than a moderate amount of back water.

Measurements by the city engineer show that the water was 3.04 feet above the curb at Broad and Sandusky Streets; 9.96 feet at Broad and Glenwood; 8.73 feet at Rich and Cypress; 9.66 at Mound and Glenwood; and about 17 feet at West Park and Sullivant Avenue.

The work of rescue went on as rapidly as the depth of water and swiftness of the currents would allow, but it was not until the 28th that the water had gone down sufficiently to allow teams to go through the streets. There was much suffering as a result, as many people were shut in without relief from Tuesday until Friday. There were many thrilling acts of rescue and many heartbreaking stories of inability to save loved ones perhaps even after escape from wrecked houses. Thirteen people were rescued from one tree alone.

There were 93 lives lost in the flood in Columbus and the deaths indirectly due to the flood bring the number up to at least 100. According to the record of the city building inspector 293 dwellings and business houses were totally destroyed, their valuation being $433,700. There were 4,071 damaged; the loss on these being $814,200. In 3,100 houses visited after the flood it has been estimated that the loss on pianos alone in Columbus amounts to $630,000; loss to furniture including musical instruments, $1,320,000; and loss to buildings and other real estate $2,250,000. It has not been possible to ascertain the mercantile loss, but a conservative estimate makes the total damage to West Columbus by the flood between $12,000,000 and $15,000,000.

The city street cleaning department removed 70,000 loads of débris at a cost of $100.000. The repairs to sewers cost $25,000, and the repairs to streets $91,000. The loss of city bridges amounts to $350,000. The loss to the county in bridges and highways was $1,200,000.

Below Columbus no very great damage was done by the high water until Chillicothe was reached. At Circleville, 27 miles below Columbus, the water reached 24.2 feet at 3 a. m., March 26, which was 4.9 feet above any previous record. The city itself is at a good elevation above the river and little damage was done.

Chillicothe, Ross County, is located at the confluence of Paint Creek with the Scioto River. The main portion of the city is built on moderately low and level land and slopes away from the Scioto River toward Paint Creek. Chillicothe is 25 miles below Circleville. The water was at 11.9 feet at 7 a. m. of March 25. At 2 p. m. it had risen only to 13.4 feet and was rising so slowly that the observer did not look at the gage when he left his work in the evening. At 2 a. m. of the 26th it had risen to 18 feet and by 6 a. m. had reached 35 feet. Its highest point was 37.8 feet at 11 a. m.

The water broke through the railroad levee at about 5.15 a. m. and about the same time was backing up through the sewers and doing some flooding. The railroad levee gave way when the water was at its highest point and fully 75 per cent of the city was flooded. The water in the east of the city was only about 1 foot higher than in 1884 but it was fully 7 feet higher in the west end, caused by the railroad line backing it up. At the river gage the water was 9.5 feet higher than the 1898 flood.

The greatest damage at Chillicothe was done in Hickory Street south of Main Street, where the water plowed out a channel from 6 to 10 feet deep the full width of the street, and in some places the houses and property abutting thereon. There were 18 deaths in Chillicothe due to the flood.

Small villages along the Scioto below Chillicothe were flooded and many houses washed away. The Norfolk & Western triple tracks at Waverly, Ohio, were twisted and wound into a corkscrew by the flood.

The city of Portsmouth, at the mouth of the Scioto River, had 75 per cent of its area under water. It is stated that when the Scioto flood was at its height it carried a current of water clear across the Ohio River that was 5 or 6 feet higher than the level of the Ohio above the current. The water was 8 to 10 feet in depth in some of the business streets in Portsmouth, and 4,500 residences were flooded.

MUSKINGUM RIVER.

The drainage area of the Muskingum River is approximately 7,693 square miles, or nearly one-fifth of the area of the State. The distance from the mouth at Marietta to the headwaters of the Tuscarawas River is 211 miles.

The northern part of the watershed is in the glaciated portion of the State and is composed of smooth, rolling plains cut into by broad stream valleys. From Muskingum County south, however, the land was not subjected to glacial action and the streams have cut deep, narrow channels. The river is navigable from Zanesville to the mouth, a distance of 70 miles. The drainage area above Zanesville is close to 6,500 square miles. The river at Zanesville is 450 feet wide at average low water.

The main branches of the Muskingum River are the Licking River, which unites with it at Zanesville from the west; the Wills Creek, which flows in from the east between Zanesville and Coshocton, and the Walhonding and Tuscarawas, which unite to form the Muskingum at Coshocton. The Licking River rises in the Licking Reservoir, which covers 3,500 acres and drains 90 square miles. The Tuscarawas River at Coshocton is 300 feet wide and the Walhonding 100 feet. The two rivers drain 4,600 square miles.

The rainfall was very heavy in Richland, Ashland, and Wayne Counties, all of the small streams at the headwaters of the larger rivers were higher than ever before known, and a great deal of damage was done. At Clinton, in Summit County, for example, near the headwaters of the Tuscarawas River, the business section was inundated by about 6 feet of water, and great damage was done.

At Massillon, in Stark County, a city of over 14,000, fully 30 per cent of the city was flooded. Thirty per cent of Mount Vernon, Knox County, was flooded; 90 per cent of Warsaw and of Nellie, both small places in Coshocton County; 50 per cent of Dresden, in Muskingum County; and 33 per cent of Belleville, in Richland County.

At New Comerstown, in Tuscarawas County, which has about 500 houses, 200 were in the flooded district, the water being from 4 to 5 feet in depth.

The headwaters of the Walhonding River began to rise on the 24th and reached their highest point on the 25th, while the Tuscarawas River did not begin to show much change until the 25th. Thus at Mount Vernon, Knox County, the highest stage was reached at noon of the 25th, and at Warsaw, just above Coshocton, the highest was at 5.30 p. m. of the 25th.

In the Tuscarawas the flood crest did not reach Massillon, Stark County, until 8 a. m. of the 26th and New Philadelphia, Tuscarawas County, not till 11 a. m. of the 27th. At Canal Dover, the highest water, 16.1 feet, was at noon of the 28th, although it stood at 15 feet from 4 p. m. of the 26th to 9 p. m. of the 27th.

Coshocton, Coshocton County, is situated on the east bank of the Tuscarawas River at its junction with the Walhonding River. The city is built on the flood plain, which is comparatively low and level. It has a population of about 10,000. The river gage was on one of the piers of the railroad bridge that crosses both rivers about 1,500 feet above their confluence. The pier stood in the Tuscarawas River. The two streams at that point are about 100 feet apart and the intervening space is overflowed with an 8-foot stage of water.

By the morning of the 25th the Walhonding River had overflowed the lowlands between the two rivers and caused a stage of 11 feet on the gage. At 2 p. m. the gage showed 14.5 feet and by 5 p. m. of the 25th the water had reached 20 feet, most of the water coming from the Walhonding River.

No more readings were possible, and before the flood subsided the bridge and river gage were washed away, 250 residences were flooded, 16 houses were washed away, and 4 people were drowned. The water rose to the second floor in 40 or 50 of the houses. Subsequent measurements determined that the highest water was 27.5 feet at 3 or 4 a. m. of the 26th. This was 5.5 feet higher than any previous record.

Approximately one-half of the village of Dresden, situated about 15 miles below Coshocton and containing some 1,600 inhabitants, was under water. The river here was 11.6 feet higher than in 1898. Several houses were washed away.

Zanesville is situated on the Muskingum River at the confluence of the Licking River. It has a population of about 29,000. Part of the city, including most of the business district, lies on the east bank of the Muskingum River, and another part west of the Muskingum, between that river and the Licking River.

The Licking River began rising on the 24th, and caused a rise in the lower pool of the Muskingum River from 9.9 feet in the morning to 11 feet by 6 p. m. At 7 a. m. of the 25th the gage in the lower pool was at 21.2 feet, and at 6 p. m. it was 28 feet, most of the water up to this time coming from the Licking River. The water began to pour down the Muskingum River by this time, and at 2 a. m. of the 26th the water at the lower gage was 35 feet, and rising at the rate of 10 inches an hour.

The water reached 39 feet at 6 a. m., 42 feet at 10 a. m., 45 feet at 2 p. m., and 48 feet at 6 p. m. At 6 a. m. of the 27th it was at 49.3 feet, and from 10 p. m. of the 27th until 3 a. m. of the 28th it stood at 51.8 feet, 15 feet higher than was registered in 1898 and 17.7 feet higher than was reached in 1884. By 7 a. m. of the 28th the water had fallen to 50.3 feet and then lowered steadily.

The river gage in the upper pool showed 39.1 feet at 6 p. m. of the 27th. Unofficial marks show that the water in the upper pool was 17 feet higher than in 1898.

At least 40 per cent of the built-up portion of Zanesville was flooded. The water was 20 feet deep at the corner of North and Third Streets, 17 feet at North and Fourth Streets, 15 feet at Market and Second Streets, and 17 feet at West Main and Luck Streets.

The business portion of the city was entirely in the flooded district. Five of the seven bridges in the city were carried out. The famous "Y" bridge, a concrete structure, was overtopped, but withstood the terrific strain, although part of the superstructure was carried away.

As the Muskingum River makes a bend to the westward around the business portion of the city there was a tendency of the flood waters to cut a new channel across the land through the heart of the business portion. The current there was exceedingly swift and destructive.

An interesting phase of the flood was the damming of the Licking River and the actual flooding upstream of this river from the Muskingum when the flood in the latter was at its height. The Licking River, which at its own flood crest was 18 inches higher than in 1898, was buried beneath the water of the Muskingum on the 27th, and the water from the Muskingum backed up the valley of the Licking for a distance of 9 miles and spread out at two points to a width of 2½ miles. This spreading out of the Muskingum in this valley, as well as in several other smaller ones, was, indeed, fortunate for Zanesville.

There were 3,441 buildings in Zanesville under water, 157 of which were entirely swept away, moved from their foundations or badly wrecked. The losses on buildings and contents at Zanesville has been estimated at $2,795,792. The loss to bridges, railroads, and telegraph and telephone companies was nearly as much more.

Zanesville was much more fortunate than many other cities in Ohio, however, because there were only 2 lives lost in the flood in this city out of nearly 15,000 which were in the flooded district. In one case a woman refused to leave her house when boatmen called to rescue her, and the other, a man, had ample time in which to save himself but delayed too long. There were many daring rescues, however.

A careful record was kept on Market Street by an interested resident, and he states that the river rose there at the rate of 6 inches an hour between 4 and 7 p. m. on the 26th, 4 inches an hour between 7 and 9 p. m., 2½ inches an hour from 9 p. m. till midnight, 1 inch an hour from midnight until 1.30 a. m. the 27th, and less than three-fourths inch an hour from that time until 9 a. m., when the crest was reached.

It was noticed in a number of cases that small frame houses that had a slate roof were overturned in the water and floated bottom up.

The relief work of the Boy Scouts in Zanesville deserves special mention. Mr. Thomas W. Lewis in his report of the flood states that every boy of the troop was on duty 21 days during the flood.

Immense damage was done in the narrow Muskingum River Valley below Zanesville. Farm buildings were destroyed and many acres of rich farming land actually washed away or covered with gravel. Out of a total of 31 houses between Zanesville and McConnelsville only 13 were left standing.

At Philo the river stage was 41.9 feet in the upper pool and 50.6 feet in the lower pool, 16 feet higher than ever before recorded. Bridges and four dwellings were swept away.

About 25 miles below Zanesville the towns of McConnelsville and Malta are located. McConnelsville has a population of nearly 2.000 and is situated on the east bank, and Malta, with about 1,000 population, is directly opposite. The river here reached a stage of 40.8 feet, or 14.4 feet higher than any previous record. The water reached a depth of 30 feet in the parts of McConnelsville nearest the river, and 28 buildings were washed away, but the greater part of this town is well up on the hillside out of flood danger.

Malta, however, is located down near the river, and 60 per cent of its was flooded and the property damage was very great. The following notes are furnished by Mr. C. H. Morris, the cooperative observer at McConnelsville:

"No; there isn't anybody worrying down the river about high water so far as I know." Thus spoke the agent on the Baltimore & Ohio northbound train from Marietta on Tuesday night, March 25, which train came in one and a half hours late, and which, incidentally, was the last train we saw for nearly three weeks.

It began raining on Sunday and the rainfall was pretty continuous until Thursday morning, when it totaled 4.43 inches. On Tuesday afternoon at 5 o'clock a message came from Zanesville stating that they expected there 10 feet more water than had ever before been recorded. We, figuring from our past experience

that the broad bottoms of the Muskingum Valley which had taken care of so much of the flood water heretofore and would do it again, counted on probably 5 feet more water here than in 1898. Well, we got it, and to spare. All day Tuesday the river rose steadily, but not alarmingly, until at dark it began rising in earnest, reaching the gage mark of 19 feet at 11 p. m. Then the people along the river front who had decided to await that morning for developments got busy, and drays, wagons, and all available persons were requisitioned for aid.

On Wednesday morning by 7 o'clock the gage showed 25 feet, being within a foot and a half of the 1898 rise, and the angry waters were piling up as never before, for at 10 a. m. they passed the former record of 26.4 feet and continued to swell at a greater rate than ever. From now until the middle of the afternoon the rate of rise was 13 inches to the hour, and at 9 p. m. the stage of water showed 36.4 feet, which was exactly 10 feet in 11 hours. At half past 12 noon the big middle span of the bridge, struck by a heavily timbered building, turned gracefully over and sank quietly in the yellow torrent. An hour later the Malta span similarly met its fate.

During the afternoon an unending procession of mills, bridges, railroad cars, barns, dwellings, everything that is indispensable to civilization, went pell-mell down the still rising waters, and darkness came again—but no sleep. Hundreds of people began making their second move. As the flood swiftly encroached upon streets heretofore far removed from the hungry river, and with all gage marks gone, Thursday morning, the 27th, dawned cold and cheerless with snow in the air.

The river now had reached a height of 39 feet, and was rising a bare 2 inches per hour, and at 9 p. m. touched its highest point, 40.8 feet, where it stood until early Friday morning. All day on Thursday the turgid Muskingum was the mecca of the inhabitants of the Twin Cities, now as far removed from each other as though in separate States, seeing each other from the hillsides, yet having no communication, and hearing nothing from the outside world either.

Malta was much more sorely hurt than McConnelsville. Not a single business there but was put out of commission. The mantel and canning factories each were carried away, the latter dropping a line of canned goods for a good mile. Parts of the main buildings of both the Hoffman tannery and the B. M. plow company drifted off. The Rogers Building—one of the landmarks of the valley—having borne the onslaughts of the ice and water for almost three-quarters of a century, and having four prosperous places of business within its walls, floated off with all its contents. The Elk Eye flouring mill—the largest building in the valley and one of oldest—lost its north wing on Thursday forenoon and went sailing away, crushing giant trees and leveling a brick house in its wake ere it got out into the river; $10,000 would not cover this one loss.

Altogether the loss of the two towns and vicinity will reach almost $500,000 in denuded farms, buildings destroyed and wrecked, and the unparalleled loss in personal effects.

The river hills at the upper end of McConnelsville closely approach the river at a point almost midway of Malta opposite, where the hill likewise juts well over the bottom land, so that when 30 feet of water is reached in the valley the current between the two towns is of tremendous swiftness. It is a curious fact that the Muskingum River floods in the past have averaged, with one exception, 14-year intervals, each exceeding the other by about 2 feet.

Beverly and Lowell, both small villages in northern Washington County, were badly flooded and much damage was done by the high water. No lives were lost. The water reached 46.5 feet at Beverly at 2 a. m., March 28, being 15.5 feet higher than ever before recorded.

Marietta is on the Ohio River at the mouth of the Muskingum River. The latter stream divides the city into two sections and enters the Ohio River at right angles. During this flood the Muskingum River rose rapidly for almost 48 hours before the Ohio River reached flood stage. The water in the Muskingum River was 6 feet higher than during the previous high-water mark of 1884, and most of the damage in Marietta was from the Muskingum.

The territory flooded in Marietta includes an area of 3.5 square miles, which was 66 per cent of the total area of the city. The flood covered the entire business portion of the city and extended to the Marietta College buildings. Sixty-seven per cent of the total number of houses in the city were flooded, with 33 per cent flooded to or above the second floor. Of this number 120 were destroyed and about 200 others were so badly damaged that they were uninhabitable. Two bridges were carried out near the mouth of the Muskingum River in Marietta at a loss of $150,000.

Some of the small towns on the Ohio River were completely submerged by the water, not a house showing above the water line.

Tables of hourly precipitation, daily and special river-gage readings, flood loss by counties, etc., follow:

TABLE 1.—*Hourly rainfall by automatic gages at the regular Weather Bureau stations in the affected district during the period Mar. 23–26, 1913.*

Date.	Rainfall by automatic gages for the hour ending—											
	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	Noon.
Mar. 23, 1913.												
Fort Wayne, Ind.								0.05	0.26	0.30	0.33	0.19
Indianapolis, Ind.							0.33	.32	.05	T.	.06	.02
Toledo, Ohio										.08	.26	.25
Dayton, Ohio								T.	.23	.09	.16	
Cincinnati, Ohio								T.		T.		
Sandusky, Ohio										.01	.23	.38
Columbus, Ohio									T.	.28	.16	.09
Cleveland, Ohio											T.	.14
Mar. 24, 1913.												
Fort Wayne, Ind.			0.10	0.30	0.20	0.08						
Indianapolis, Ind.	T.	T.	T.	.02	.06	.25	.12	.11	.08	.02	.04	.01
Toledo, Ohio	0.01	0.12	.10	.10	.03	.09	.10	.12				
Dayton, Ohio		T.	.02	.01	.01	T.	T.	.63	.18	.18	.09	.08
Cincinnati, Ohio			.01	.09	.15	.16	T.	T.	.35	.30	.16	.07
Sandusky, Ohio			.17	T.	.04	.08	.08	.02	.09	.07	T.	T.
Columbus, Ohio					.02	.04	.03	T.	.49	.12	.15	.26
Cleveland, Ohio		T.	T.				.03	.08	.05	.14	.06	T.
Parkersburg, W. Va.								T.				
Erie, Pa.					.02	.02	T.	T.	.01	.10	.07	.09
Pittsburgh, Pa.									T.	.02		T.
Mar. 25, 1913.												
Fort Wayne, Ind.	.10	.18	.02	.02	.14	.14	.02	T.				
Indianapolis, Ind.	.22	.18	.05	.19	.36	.06	.02			.04	T.	T.
Toledo, Ohio	.33	.23	.42	.02	.01	.18	.23	.04	T.			
Dayton, Ohio	.02	.04	.58	.21	.15	.16	.30	.24	.06	.04	.20	.12
Cincinnati, Ohio			.10	.01	.09	.01	.41	.46	.15	.13	.30	.04
Sandusky, Ohio	.36	.24	.32	.25	.12	.12	.20	.14	.07	T.		T.
Columbus, Ohio	.01			.06	.40	.05	.07	.18	.13	.16	.06	.15
Cleveland, Ohio	.18	.28	.26	.27	.24	.12	.11	.27	.14	.06	T.	T.
Parkersburg, W. Va.							T.	T.				.18
Erie, Pa.	.13	.10	.27	.25	.22	.18	.17	.11	.10	.18	.18	.08
Pittsburgh, Pa.							T.				T.	.08
Mar. 26, 1913.												
Toledo, Ohio	.01	.01	T.									
Cincinnati, Ohio	.11	.05	.02	.02						T.	.03	.11
Sandusky, Ohio	T.	T.	.02	T.								
Columbus, Ohio	.17	.16	.04	.03								.05
Cleveland, Ohio	.05	T.	T.	T.								
Parkersburg, W. Va.	T.	.04	.22	.24	.18	.09	.02	.01	T.		.01	.04
Erie, Pa.	.12	.05	.08	.02	T.	.01	.02	.02	T.	T.	T.	.01
Pittsburgh, Pa.	.25	.07	.33	.18	.14	.18	.02					

Date.	Rainfall by automatic gages for the hour ending—												
	1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p.m.	11 p.m.	Mid-night.	Total.
Mar. 23, 1913.													
Fort Wayne, Ind.	0.25	0.28	0.20	0.10	0.11	0.01							2.08
Indianapolis, Ind.	.01	.02	.33	.11							T.	0.02	1.27
Toledo, Ohio	.16	.20	.28	.18	.20	.09	0.20	T.					1.90
Dayton, Ohio													.48
Cincinnati, Ohio													T.
Sandusky, Ohio	.30	.30	.29	.19	.23	.12	.14	0.01					2.20
Columbus, Ohio	T.												.53
Cleveland, Ohio	.28	.31	.37	.19	.21	.15	.09	.20	T.				1.94
Parkersburg, W. Va.	T.	.08											.08
Erie, Pa.	T.	.09	.17	.25	.15	.08	.04	.17	0.11	0.13	0.09		1.28
Pittsburgh, Pa.		T.	.08	.10	.02								.20

TABLE 1.—*Hourly rainfall by automatic gages at the regular Weather Bureau stations in the affected district during the period Mar. 23-26, 1912*—Continued.

Date.	Rainfall by automatic gages for the hour ending—												
	1 p.m.	2 p.m.	3 p.m.	4 p.m.	5 p.m.	6 p.m.	7 p.m.	8 p.m.	9 p.m.	10 p.m.	11 p.m.	Midnight.	Total.
Mar. 24, 1913.													
Fort Wayne, Ind	T.	0.17	0.07	0.01	0.10	0.07	0.20	0.22	0.09	0.07	0.22	0.08	1.98
Indianapolis, Ind	0.23	.08	.16	.17	.08	.02	.33	.22	.18	.16	.21	.21	2.76
Toledo, Ohio	T.	T.	.06	.09	.02	.05	.07	.09	.14	.24	.19	.20	1.82
Dayton, Ohio	.03	.03	.01	.58	.14	.10	.49	.16	.14	......	T.	.07	2.95
Cincinnati, Ohio	T.	T.	......	......	.67	.25	T.	......	......	......	......	......	2.21
Sandusky, Ohio	......	.02	.09	.18	.15	.06	.09	.03	.11	.04	.06	.20	1.58
Columbus, Ohio	.19	.07	.08	T.	.17	.37	.10	.05	.05	......	......	......	2.14
Cleveland, Ohio	T.	......	.02	.16	.07	.22	.04	.02	.12	.25	.12	.08	1.46
Parkersburg, W. Va	......	......	.05	T.	......	......	......	......	......	......	......	......	.05
Erie, Pa	......	......	......	......	.05	.08	.16	.19	.17	.07	.08	.27	1.38
Pittsburgh, Pa	T.	.01	.01	.16	.22	T.	T.	T.	.10	.07	.13	T.	.72
Mar. 25, 1913.													
Fort Wayne, Ind	......	T.	T.	T.	.01	.02	.02	.01	T.	.01	......	......	.69
Indianapolis, Ind	.02	T.	.01	.01	.02	.17	.17	.04	T.	......	......	......	1.56
Toledo, Ohio	T.	.01	.01	.01	.02	.02	.01	.01	.05	.10	.02	.02	1.74
Dayton, Ohio	T.	.04	T.	.07	[1] .04	......	......	......	......	......	......	......	[2] 2.27
Cincinnati, Ohio	T.	.05	T.	.02	.03	.18	1.12	.28	.23	.12	.21	.21	4.15
Sandusky, Ohio	......	......	......	T.	.01	T.	.02	.09	.05	.05	.01	T.	2.05
Columbus, Ohio	.12	T.	.02	.04	.03	.05	.28	.31	.29	.18	.15	.15	2.89
Cleveland, Ohio	T.	......	......	......	T.	T.	.04	.06	.21	.14	.11	.17	2.66
Parkersburg, W. Va	.07	.01	.19	.06	.06	......	......	.08	T.	.08	.07	T.	.80
Erie, Pa	T.	......	......	......	......	......	......	......	T.	.01	.05	.09	.212
Pittsburgh, Pa	.03	......	T.	.08	T.	T.	.04	.03	.01	.07	T.	.21	.55
Mar. 26, 1913.													
Toledo, Ohio	......	......	.02	.10	.10	.05	.04	.03	.03	.03	.03	.03	.48
Cincinnati, Ohio	.02	.03	.11	.07	.10	.06	.03	.17	.16	.01	T.	.01	1.11
Sandusky, Ohio	......	......	.02	.05	.11	.11	.11	.14	.14	.13	.06	.06	.95
Columbus, Ohio	.05	.02	.03	.19	.04	.01	.18	.04	.08	.15	.05	.11	1.40
Cleveland, Ohio	.01	.01	.09	.12	.07	.08	.09	.05	.04	.07	.18	.03	.91
Parkersburg, W. Va	.04	.04	.02	.02	.01	......	.22	.13	.21	.09	.12	.09	1.84
Erie, Pa	......	......	T.	T.	.12	.12	.03	.07	.06	.07	.05	.06	.91
Pittsburgh, Pa	T.	......	T.	.01	T.	.05	.12	.07	.04	.10	.06	.04	1.66

[1] Clock on triple register stopped at 4.30 p. m.
[2] Total to 4.30 p. m.

TABLE 2.—*Average daily rainfall and the total rainfall for the period Mar. 23-27, 1913, arranged by watersheds; also the area of the watersheds, and the total fall in cubic feet per square mile.*

Watersheds.	Rainfall for 24 hours ending 7 p. m.—					Total.	Areas of watersheds in square miles.	Total fall in cubic feet per square mile.
	23d.	24th.	25th.	26th.	27th.			
Sandusky	2.02	1.56	2.92	0.91	0.81	8.22	1,554	19,096,000
Mahoning	1.26	1.36	2.90	1.10	.71	7.33	1,025	17,029,000
Great Miami, above Dayton	.92	1.94	3.82	1.41	.48	8.57	2,558	19,920,000
Great Miami, total	.66	2.22	3.82	1.50	.42	8.62	5,400	20,026,000
Little Miami	.32	2.09	2.54	2.07	.51	7.53	1,709	17,494,000
Scioto, above Columbus	1.16	1.90	3.25	1.76	.60	8.68	1,567	20,065,000
Scioto, total	.71	1.52	2.48	2.00	.62	7.33	6,301	17,029,000
Muskingum, above Zanesville	.66	1.26	2.62	1.73	.65	6.92	6,509	16,076,000
Muskingum, total	.55	1.17	2.22	1.87	.63	6.44	7,693	14,961,000

TABLE 3.—*Daily river-gage readings during the period Mar. 24–28, 1913, and the highest stage reached with the hour and date of its occurrence, the flood stage, the highest previous stage and the month and year of its occurrence, and the amount in feet and tenths of feet that the stage in 1913 exceeded the highest previous stage.*

[All daily readings were made at 7 a. m., except where marked with a star (*).]

Stations.	Mar. 24.	Mar. 25.	Mar. 26.	Mar. 27.	Mar. 28.	Highest stage.	Date.	Hour.	Flood stage.	Highest previous reading.	Year.	Month.	Excess in 1913.
Sandusky River:													
Upper Sandusky	16.8	*19.0	17.6	16.0	13.5	19.0	25	9 a. m.	13.0	16.0	1883	Feb.	3.0
Tiffin	7.0	12.5	19.4	16.0	12.0	19.4	26	6 a. m.	7.0	11.4	1904	Apr.	8.0
Fremont	9.4	13.5	*21.5	21.5	14.3	21.5	26	About noon.	10.0	17.8	1884	Feb.	3.7
Great Miami:													
Piqua	8.7	23.7	15.0	12.0	10.3	24.0	25	10 a. m.	12.0	16.0			8.0
Dayton	7.0	24.0	28.1	22.2	15.7	29.0	25	12 midnight.	18.0	21.3	1866	Sept.	7.7
Hamilton	4.8	19.6	*34.6	*25.0	*19.2	34.6	26	3 a. m.	12.0	23.3	1898	Mar.	11.3
Little Miami:													
Oregonia	7.0	18.0	21.1			21.1	25	11 p. m.	10.0	20.4	1897	Mar.	.7
Kings Mills	3.3	17.8	33.7			33.7	26	3.50 a. m.	17.0	27.2	1897	Mar.	6.5
Scioto:													
Prospect	*8.5					20.0	26		9.0	15.5	1904	Apr	4.5
Delaware	5.5	*27.5				27.5	25	Noon.	9.0	16.3	1904	Apr.	11.2
Columbus Reservoir	1.8	9.3	10.4	8.9	6.6	12.8	25	2.30 p. m.		5.5	1909	Feb.	7.3
Columbus	6.2	21.9	20.9	19.7	17.4	22.9	25	11 a. m.	17.0	21.3	1898	Mar.	1.6
Circleville		11.6	24.2	20.3	16.2	24.2	26	3 a. m.	12.0	19.3	1884	July	4.9
Chillicothe	1.6	11.9	*37.8			37.8	26	11 a. m.	14.5	28.3	1898	Mar.	9.5
Muskingum:													
Canal Dover	2.3	7.0	13.0	15.0	16.1	16.1	28	Noon.	9.0	12.0			4.1
Coshocton	2.5	11.0	*27.5			27.5	26	4 a. m.	8.0	22.0	1898	Mar.	5.5
Zanesville	9.9	21.2	*39.0	*51.8	50.3	51.8	27	10 p. m.	25.0	36.8	1898	Mar.	15.0
McConnelsville			24.3	*40.8		40.8	27	9 p. m.	15.0	26.4	1898	Mar.	14.4
Beverly	7.7	16.6			*46.5	46.5	28	2 a. m.	25.0	35.0	1898	Mar.	15.5

TABLE 4.—*Special river gage readings of rivers in Ohio, Mar. 24–27, 1913.*

Date.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	Noon.
Sandusky River:												
Tiffin—												
Mar. 24							7.0					
Mar. 25							12.5				14.0	
Mar. 26							19.4					
Fremont—												
Mar. 24							9.4			10.5		
Mar. 25							13.5	14.7	15.2			
Mar. 26												21.5
Great Miami River:												
Piqua—												
Mar. 23												
Mar. 24							8.7	8.9				
Mar. 25							23.7			24.0		24.0
Dayton—												
Mar. 24							7.0					11.6
Mar. 25							24.0					
Mar. 26							28.1					
Hamilton—												
Mar. 24							4.8					8.8
Mar. 25						18.8	19.6	20.5	21.7	22.2	24.8	
Mar. 26			34.6									
Little Miami River:												
King Mills—												
Mar. 24							3.3					6.3
Mar. 25							17.8			19.5		
Mar. 26							33.7					

TABLE 4.—*Special river gage readings of rivers in Ohio, Mar. 24-27, 1913*—Continued.

Date.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	Noon.
Scioto River:												
Delaware—												
Mar. 24							5.5					
Mar. 25	16.8	18.2										27.5
Columbus Reservoir—												
Mar. 24							1.8				2.8	
Mar. 25						8.9	9.5		10.7	11.7	12.5	
Mar. 26							10.4					
Mar. 27							8.9			8.4		
Columbus—												
Mar. 24							6.2					
Mar. 25						21.5	21.9	21.9	22.2	22.6	22.9	22.9
Mar. 26	21.5	21.3	21.0	21.0	21.0	21.0	20.9	20.8	20.7	20.5	20.2	20.1
Mar. 27							19.7		19.6			
Mar. 28							17.4				17.1	16.9
Mar. 29							14.7	14.6	14.5			14.2
Chillicothe—												
Mar. 25							11.9					
Mar. 26		18.0				35.0					37.8	
Muskingum River:												
Canal Dover—												
Mar. 25							7.0					
Mar. 26							13.0					
Mar. 27							15.0					
Mar. 28							16.1					16.1
Coshocton—												
Mar. 24							2.5					
Mar. 25							11.0					
Mar. 26				27.5								
Zanesville—												
Mar. 25							21.2					
Mar. 26		35.0				39.0				42.0		
Mar. 27						49.3						
Mar. 28			51.8				50.3					
McConnelsville—												
Mar. 25												
Mar. 26							25.0			26.4		
Mar. 27												

Date.	1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	Midnight.
Sandusky River:												
Tiffin—												
Mar. 24	7.8											
Mar. 25												
Mar. 26												
Fremont—												
Mar. 24	11.5		11.8				12.4					
Mar. 25			17.5									
Mar. 26			21.5			21.5						
Great Miami River:												
Piqua—												
Mar. 23							5.0					
Mar. 24					11.0				14.0			
Mar. 25		24.0										
Dayton—												
Mar. 24		12.0		12.2				14.2		15.3		
Mar. 25												29.0
Mar. 26												
Hamilton—												
Mar. 24	9.8	10.6	11.0	11.7	12.0							
Mar. 25					25.0							
Mar. 26												

TABLE 4.—*Special river gage readings of rivers in Ohio, Mar. 24–27, 1913*—Continued.

Date.	1 p.m.	2 p.m.	3 p.m.	4 p.m.	5 p.m.	6 p.m.	7 p.m.	8 p.m.	9 p.m.	10 p.m.	11 p.m.	Midnight.
Little Miami River:												
Kings Mills—												
Mar. 24	10.7		13.8									
Mar. 25		22.0										
Mar. 26												
Scioto River:												
Delaware—												
Mar. 24		8.5								13.8	14.5	14.9
Mar. 25												
Columbus Reservoir—												
Mar. 24		3.3		4.3		4.8		6.0		6.4		6.7
Mar. 25	12.7		12.8		12.7	12.4		11.7				
Mar. 26		9.4			9.3	9.3						
Mar. 27					7.8							
Columbus—												
Mar. 24	8.8			13.8	14.2	15.0	15.5	16.1	16.8	17.6	18.4	18.8
Mar. 25	22.2	22.1	22.0	22.0	22.0	22.0	22.0	22.2	22.2	22.0	21.7	21.5
Mar. 26	20.1	20.1	20.0									
Mar. 27				18.5								
Mar. 28	16.8	16.7	16.6	16.5	16.4							
Mar. 29	13.9		13.9		13.7							
Chillicothe—												
Mar. 25		13.4										
Mar. 26												
Muskingum River:												
Canal Dover—												
Mar. 25											10.6	
Mar. 26				15.0								
Mar. 27									15.0			
Mar. 28												
Coshocton—												
Mar. 24												
Mar. 25		14.5			20.0							
Mar. 26												
Zanesville—												
Mar. 25						28.0						
Mar. 26		45.0				48.0						
Mar. 27										51.8		
Mar. 28												
McConnelsville—												
Mar. 25											19.0	
Mar. 26												
Mar. 27						40.4			40.8			

TABLE 5.—*Monetary loss to highways and bridges, buildings and personal property, cost of cleaning and repairing basements and machinery, damage to crops and live stock, and number of lives lost.*

Counties.	Damage to public highways and bridges.	Damage to buildings and personal property.	Cost of cleaning basements, repairing machinery and other equipment.	Crops destroyed or damaged.	Loss of live stock.	Number lives lost.
Adams	$8,000				$4,200	
Allen	81,600	$73,850			3,200	1
Ashland	110,000	100,000	$100		1,100	1
Ashtabula	80,000	Small.	Small.	0	400	0
Athens	30,000	10,000	2,000	$500	0	0
Auglaize	58,000	10,000	500	0	650	0
Belmont	5,500					
Brown	15,000					
Butler	600,000	15,000,000	300,000	50,000	17,000	98
Carroll	0	0	0	0	100	0
Champaign	70,000				3,100	

TABLE 5.—*Monetary loss to highways and bridges, buildings and personal property, cost of cleaning and repairing basements and machinery, damage to crops and live stock, etc.*—Continued.

Counties.	Damage to public highways and bridges.	Damage to buildings and personal property.	Cost of cleaning basements, repairing machinery and other equipment.	Crops destroyed or damaged.	Loss of live stock.	Number lives lost.
Clark	$100,000				$1,000	
Clermont	25,000				500	
Clinton					1,000	
Columbiana	2,700	$75,000	$5,000	Small.	Small.	0
Coshocton	200,000	200,000	6,000	$50,000	610	4
Crawford	45,000	25,000	5,000	3,000	400	1
Cuyahoga	200,000	300,000				
Darke					1,200	
Defiance	90,000	350,000			1,300	
Delaware	424,000	355,000	10,000	10,000	3,150	22
Erie	5,500	0	0	0	0	0
Fairfield	55,000	20,000	1,000	2,000	1,300	0
Fayette	15,000	10,000	5,000	40,000	500	
Franklin	1,550,000	15,000,000			3,800	93
Fulton	20,000	Small.	0	Small.	0	2
Gallia	30,000				213	
Geauga	21,000	500	0	0	0	0
Green	40,000				10,400	
Guernsey	10,000			6,000	725	0
Hamilton	1,000,000	350,000	100,000	10,000	7,100	5
Hancock	9,700	1,000,000			1,500	
Hardin	45,264	5,000	5,000	25,000	1,000	2
Harrison	2,500	1,500	Small.	Small.	300	
Henry	20,000	5,000				1
Highland						
Hocking	15,600	100,000	1,000	1,000	100	0
Holmes	39,500				150	
Huron	52,000				750	
Jackson	0	0	0	0	0	0
Jefferson	41,000					
Knox	150,000	20,000	15,000	5,000	500	3
Lake	2,000	1,000	500	200	300	0
Lawrence	10,000					
Licking	31,800	10,000	3,000	5,000	1,075	1
Logan	38,500	Small.	Small.	7,000	900	
Lorain	65,000	30,000	Small.	2,000	600	3
Lucas	75,000	50,000	5,000	Small.	Small.	2
Madison	85,000	1,000	0	1,000	0	0
Mahoning	46,000	125,000	50,000	15,000	1,000	3
Marion	65,000				525	
Medina	75,000					
Meigs	20,000	1,000,000	100,000	100,000	10,000	
Mercer	7,600	0	0	0	0	0
Miami	550,000	2,000,000	60,000	60,000	2,800	60
Monroe	7,000	12,000	1,000	0	25	0
Montgomery	1,350,000	32,000,000	2,500,000	250,000	50,000	97
Morgan	175,000	434,800	4,000	30,000	400	0
Morrow	75,000	25,000		10,000	100	4
Muskingum	450,000	2,700,000	250,000		200	3
Noble	0				2,000	
Ottawa	2,000				200	
Paulding	25,000	75,000	2,000	0	750	0
Perry	15,000				750	1
Pickaway	400,000	50,000	2,000	15,000	1,000	1
Pike	97,700	350,000	2,000	40,000	12,025	
Portage	42,500	200,000	10,000	100,000	5,000	0
Preble	41,000				700	
Putman	1,150				4,100	
Richland	150,000	100,000	50,000	25,000	300	1
Ross	314,325	1,340,000	30,000	20,000	19,200	20

TABLE 5.—*Monetary loss to highways and bridges, buildings and personal property, cost of cleaning and repairing basements and machinery, damage to crops and live stock, etc.*—Continued.

Counties.	Damage to public highways and bridges.	Damage to buildings and personal property.	Cost of cleaning basements, repairing machinery and other equipment.	Crops destroyed or damaged.	Loss of live stock.	Number lives lost.
Sandusky	$65,500	$300,000	$5,000	$5,000	$1,800	3
Scioto	325,000	....	....	....	....	....
Seneca	300,000	702,737	70,000	50,000	1,200	19
Shelby	120,000	35,000	30,000	40,000	1,200	0
Stark	225,000	300,000	50,000	10,000	350	3
Summit	240,000	100,000	Small.	Small.	1,200	....
Trumbull	125,000	600,000	....	....	3,500	2
Tuscarawas	200,000	50,000	10,000	40,000	8,000	1
Union	225,000	Small.	0	0	925	0
Van Wert	7,000	25,000	15,000	20,000	500	0
Vinton	100	0	0	100	0	0
Warren	300,000	400,000	50,000	50,000	30,000	8
Washington	180,000	2,000,000	....	300,000	200	....
Wayne	100,000	25,000	2,000	10,000	1,250	2
Williams	5,000	....	....	Small.	Small.	0
Wood	70,000	20,000	5,000	5,000	2,500	....
Wyandotte	60,000	0	0	....	1,100	0
Total	12,031,039	78,072,387	3,762,100	1,412,800	234,953	467

FLOOD IN THE WHITE RIVER OF INDIANA, MARCH, 1913.

By C. E. NORQUEST, *Acting Section Director.*

The flood of March, 1913, is without a parallel in the history of Indiana. Water stages reached were from 2 to 8 feet higher than those recorded in any previous flood; the loss of life and property was unprecedented; thousands were driven from their homes, fleeing for their lives; transportation lines were helpless through loss of track and bridges; telephone and telegraph lines were crippled; communities were cut off from communication with the outside word for from 24 to 48 hours; cities were deprived of light and power by the flooding of power plants; isolated towns were threatened with famine; and for a period of three days or more the great commercial enterprises of the State were at a standstill. To this stupendous toll of loss by flood the White River watershed contributed a large share. The East and West Forks of the White River flow through a populous and prosperous section of the State, and many thriving towns and cities are situated along their banks and on their tributary streams. It follows that flood stages must be attended by property loss, and when the streams rise so much higher than could be reasonably expected, in the light of past experience such unusually high water must be attended by enormous destruction of property.

THE WHITE RIVER VALLEY.

The basin of the White River comprises more than one-third the total area of the State. The drainage area is approximately 11,300 square miles, about equally divided between the East and West Forks. The valleys of the two forks are of nearly equal length, about 275 miles, and their topography is somewhat similar, both valleys being flat and broad and subject to overflow; the West Fork has an average fall of 3 feet per mile, the East Fork a little less. Both streams flow through an excellent farming region, and the bottom lands comprise some of the most valuable farm land of the section. The East Fork, because it has the less fall, has a greater tendency to meander in its course, and also to change its course during high water, a tendency that proved particularly destructive to farm land during the recent flood. The tributaries of these main streams are generally short and rapid streams that rise quickly after heavy rains and subside with equal rapidity.

THE HEAVY RAINFALL OF MARCH 23–27, 1913.

The immediate cause of the great flood of March, 1913, was the unprecedentedly heavy rainfall of March 23 to 27. Contributory causes, such as the obstruction or narrowing of channels, no doubt added to the disastrous results in some communities.

The meteorological records for this region show isolated cases where at a single station a greater amount of rainfall has occurred in an equal period of time, but never before in the history of the State, as far back as records extend, has so great a depth of precipitation occurred so uniformly over the entire watershed in so short a period of time. The worst previous flood of the White River was that of March, 1904. The rain causing that flood began on March 24 and continued for two days, heavy rainfall extending generally over the entire watershed. The average rainfall for seven stations, about equally distributed over the watershed of the West

Fork, was 4.97 inches, as against 7.81 inches recorded during the recent flood. The average for eight stations distributed over the watershed of the East Fork was 4.19 inches for the flood of 1904, as compared with 8.41 inches for the flood of 1913. It is also worthy of note that at most of these stations more rain fell within 24 hours during the 1913 flood than was recorded in 48 hours during the flood of 1904. This tremendous downpour occurred over a drainage basin the soil of which was already well saturated by previous rains, and whose streams were already carrying their normal spring flow.

Stations reporting precipitation in excess of 5 inches for 24 consecutive hours (see also Table 2).

Station.	Amount.	Date.
Bloomington	6.56	Mar. 25
Columbus	7.00	Do.
Elliston	6.10	Do.
Mauzy	5.59	Do.
Nashville	6.01	Do.
Seymour	5.43	Do.
Shoals	6.66	Mar. 24
Washington	6.10	Mar. 25

The average precipitation for the White River watershed, as determined from 20 stations, on March 24 was 2.42 inches; on the 25th, 4.05 inches.

RIVER STAGES.

The Weather Bureau maintains regular gaging stations on the White River at Anderson, Indianapolis, Shoals, and Elliston. At each of these stations the stages reached during the flood of 1913 are the highest ever recorded, and from other towns and cities along the rivers it is generally reported that the stages reached are the highest ever known.

Crest stages as compared with previous highest water.

Station.	Flood stage.	Previous highest stage.		1913		
		Height.	Date.	Highest.	Date.	Compared with previous highest.
Anderson	9	18.8	Mar. 23, 1904	22.1	Mar. 25	+3.3
Indianapolis	12	19.5	Apr. 1, 1904	25.7	...do.....	+6.2
Elliston	21	29.6	Mar. 5, 1897	31.3	Mar. 27	+1.7
Shoals	20	34.1	Mar. 30, 1904	42.2	Mar. 28	+8.1

The crest of the flood passed along the upper reaches of the streams during the 25th and 26th, along the middle courses on the 26th and 27th, and along the lower courses on the 27th and 28th.

The following records of daily gage readings taken at 7 a. m., ninetieth meridian time, show admirably the rapid rate at which the rivers rose. The sharp rise caused by the excessive precipitation of the night of the 24th–25th is noteworthy.

Station.	22d.	23d.	24th.	25th.	26th.	27th.	28th.	29th.
Anderson	4.3	3.8	11.8	17.6	20.6	14.0	10.2	7.8
Indianapolis	4.7	....	11.0	18.0	(1)	....	....	....
Elliston	....	....	11.8	23.8	27.8	31.3	30.4	28.6
Shoals	7.4	8.0	8.8	21.6	29.5	37.0	42.2	41.7

[1] The Indianapolis gage was washed away during the night of 25th–26th.

FIG. 11.—WASHINGTON STREET BRIDGE, INDIANAPOLIS, IND., LOOKING DOWNSTREAM.

FIG. 12.—INDIANAPOLIS WATERWORKS CO. WEATHER BUREAU RIVER GAGE SHELTER, SMALL ROUND BUILDING LEFT CENTER OF PICTURE.

FLOOD SUMMARY.

Frequent moderate rains had been general over the State from the beginning of the month, and on the 20th and 21st heavy rains occurred. As a result the soil was pretty thoroughly saturated and the streams carrying a considerable volume of water when the storms of the 23d to 27th set in.

Rain began in the early morning of the 23d and continued almost unceasingly until the 26th, when the steady downpour gave way to showery conditions. By the evening of the 24th the smaller streams tributary to the White River were overflowing into the lowlands. At Elwood, in Madison County, Duck Creek was 30 inches higher than in 1904; one-third of the town was inundated, and over 100 families had been rescued from flooded homes. At Broad Ripple, a suburb of Indianapolis, White River was spreading over the lowlands, and many families were abandoning their homes. Fall Creek was out of its banks in northeastern Indianapolis, and families in that part of the city were moving out. Eagle Creek on the west side was far beyond its banks, and people were moving to higher ground as rapidly as conveyances could be secured. The White River was out over the bottoms along its upper reaches in Randolph and Madison Counties, and farmers were driving their stock to higher ground.

During the night of the 24th–25th the rainfall was the heaviest of the flood period. Its effect is apparent in the river stages recorded on the morning of the 25th. The White River was out of its banks throughout its entire course and rising rapidly. By 9 a. m. the river at Indianapolis had reached 19.6 feet, passing the mark of 19.5 feet set by the flood of 1904. At Muncie the high water of 1904 was exceeded by 1 foot; 400 dwellings were surrounded by water; city water service was cut off; all railway communication discontinued. One hundred families had been driven from their homes at Johnstown. At Anderson 1,000 persons had been routed from their homes by water. Martinsville was cut off by washouts on steam and electric lines and many houses were under water. At Tipton more than 100 families had moved to higher ground; the city was in darkness, the light and power plant being under water. At Petersburg the White River rose 8 feet during the night; every house in the western part of the city was flooded; mines and factories all closed. In Indianapolis the West Washington and West New York Street lowlands were inundated, and from these flooded districts the rising waters were spreading into the bottom lands of West Indianapolis behind the levee; by noon the fires under the boilers in the power houses of the Indianapolis Water Co. and the street railway company were drowned, leaving the city without water for fire protection and without street-car service. Steam roads and trolley lines throughout the flood district were tied up by washouts and unsafe or down bridges; towns were isolated; the wildest rumors were rife of entire communities being swept away by constantly rising waters. The local office of the Weather Bureau issued the following warning:

> Below Indianapolis the river will rise rapidly and the public should prepare for higher stages than have been experienced for many years. Every precaution should be taken by those living along the lower course of the river, as the rise will be unusually rapid and will reach a point several feet above the danger line.

The crest of the flood passed Indianapolis on the morning of the 26th. The Washington Street highway bridge, Indianapolis & Vincennes Railroad Bridge, Vandalia Railroad Bridge, and a private bridge belonging to Kingan & Co., no longer able to withstand the force of the water and the pounding of débris hurled against them, gave way during the day. The levee along the west bank of the river, built to protect West Indianapolis from high water, began to crumble and give way at 10 a. m., allowing a great volume of water to rush into that portion of the city, but, as the people had been amply warned of the weakened condition of the levee and the probability of a break, none was taken unaware and few lives were lost, although many who refused to give heed to the warnings had to be rescued from the windows and roofs of houses and from trees and telephone poles. Many weird and pitiful stories are told of the suffering and privations of those who were obliged to spend the night perched on a roof or in trees.

Reports during the day gave the assurance that on the upper reaches of the river the flood was subsiding rapidly, though along the lower courses the river continued to rise, the crest not passing at Elliston until the 27th.

The morning of the 28th broke bright and clear; no more rain fell during the rest of the month and the flood waters on the White River watershed continued to recede, rapidly in the upper courses of the streams and more slowly along the lower reaches.

LOSS OF LIFE AND PROPERTY—WHITE RIVER WATERSHED.

When the high stages and rapid rise of streams are considered the loss of life is surprisingly small; only 12 deaths, 5 of which occurred in Indianapolis, being due directly to the flood.

The property loss, while heavy and beyond question the greatest flood loss ever experienced in this district, is not nearly so great as at first estimated. The heaviest loss was suffered in the city of Indianapolis, where an area of approximately 6 square miles was inundated. This area comprised park, residence, and factory districts. Four thousand families were driven from their homes by the water, and a majority of these suffered practically a total loss of their household goods.

Crop losses for the district would have been much larger had the flood occurred during the crop season; as it was the damage was confined to winter wheat and hay crops. Great damage resulted from erosion and the deposit of sand and gravel over areas that had been fertile farm soil. In some localities whole farms were covered with sand to such a depth as to render the land worthless for farm purposes for many years; in others the top soil was washed away to such an extent that the land is now unfit for farming. Damage of this character occurred chiefly along the lower courses of the rivers.

The values given in the following table have been secured from reliable sources and are believed to be a fair and conservative estimate of the losses sustained over the White River watershed:

Money value of property destroyed or damaged, including public highways and bridges, also the cost of cleaning up basements and putting machinery and equipment in serviceable condition	$4,659,855
Money value of crops destroyed, or amount of damage thereto	262,500
Money value of live stock or other farm products lost	51,150
Money value of losses occasioned by enforced suspension of business through flood, including wages of employees	622,600
Loss in the State to railroads and trolley lines	4,807,555
Loss in Wabash Valley	10,000,000
Total loss in Indiana, all classes	20,403,660

FLOOD ON THE WABASH RIVER IN MARCH, 1913.

By W. R. CADE, *Observer, United States Weather Bureau.*

On Sunday morning, March 23, river-gage readings from the different stations on the Wabash River indicated a stage of water somewhat below the normal height for the time of year. Bluffton reported a stage of 2.5 feet; Logansport, 3.8; Attica, 6.8, and at Terre Haute the stage was 7 feet. The river was falling at all points, and no one entertained the idea that within three or four days the greatest flood on record in the Wabash Valley would have reached its climax. A heavy rain fell on March 23 over the entire district drained by the river, and at 7 o'clock the following morning 3.80 inches was measured at Bluffton, 2.82 at Logansport, 2.80 at Attica, and 0.99 inch at Terre Haute. This heavy rain caused the river to rise at a record-breaking rate, and at 7 o'clock Monday morning, March 24, the river had risen to a stage of 12.3 at Bluffton, 12.1 at Logansport, 15.9 at Attica, and 14.5 feet at Terre Haute. This meant a river above flood stage (12 feet) at Bluffton, Logansport, and Attica, and rapidly approaching the flood stage of 16 feet at Terre Haute.

The heavy rain continued and the amounts on Tuesday were equally as large as those of Monday. The amount of rain over the valley during this period ranged from 2 to 3 inches, and the river continued to rise very rapidly. At 7 a. m. Tuesday, March 25, the following river stages were observed: Bluffton, 17.5; Attica, 24.6; Terre Haute, 19.5. During the afternoon of the preceding day (Mar. 24) the bridge on which the river gage at Logansport was installed was washed away, so that further readings from this point were impossible.

The next day, Wednesday, March 26, the rain was only slight, but the river continued rising. The crest of the flood passed Bluffton and Logansport on this date, Bluffton recording a stage of 20 feet and the Logansport's observer being unable to make a reading.[1]

During the 24 hours ending March 27 about half an inch of rain fell over the valley, which, fortunately, was the last measurable quantity of precipitation until March 31. On the 27th the crest of the flood reached Attica, a stage of 33.4 feet being reached, which was 21.4 feet above the flood stage, the highest water ever recorded. The highest water at Terre Haute was also recorded on this date. At 10 a. m. a stage of 31.3 feet was reached, and the water remained at this point for 4 hours, at the end of which time it began to fall slowly.

When the river at Terre Haute reached a stage of 19 feet the residents of a little settlement of about 400 inhabitants, known as Taylorville, on the west side of the river, began to leave their homes. Within a day after they left their houses the entire place was submerged. The people living in Taylorville and in West Terre Haute were advised through the newspapers by the local office to prepare for a high river which was fast approaching the city. West Terre Haute, also on the west side of the river, suffered considerable damage during the flood. For the first time in the history of this town, which has a population of 4,000, the water covered its main street, and was several inches high on the floors of the stores and other business houses on this street.

[1] Later it was determined that the river reached a stage of 22.5 feet.

By Tuesday morning, March 25, the water had driven the Taylorville people from their houses, and the next day the lower parts of West Terre Haute were inundated. It was on this day, March 26, that the river began its work of destruction on the Terre Haute side. The water, gas, electric, and other plants, including four large distilleries, along the river fought the rising water with sandbags, pumps, and other means. On the evening of March 26 a levee north of Terre Haute broke and a large section of the north end of town was covered with a foot or two of water.

The river stage on Thursday morning, March 27, was 31.2 feet, and the water was rising slowly. A few hours after this reading the crest of the flood was reached, 31.3 feet. The water remained at this height for several hours and then began to slowly recede. At 8 a. m., this date, the city gas plant shut down, and the electric plant discontinued operations about 45 minutes later. The water had been bravely fought at these places, but when the river reached 31 feet it was necessary to abandon further efforts in this direction.

Of course, with the shutting down of the electric plant, the street-car service of the city was stopped, and on the night of March 27 the city was wrapped in darkness. Very few business houses generated their own electricity, and business on this night was conducted in candle and lamp light. People walking along the main street of the city carried lanterns, and the streets in the resident parts of town were illuminated only by the faint beams from a candle or a lamp coming through an open window. The city was without electricity until early in the morning of the 28th, and gas was not supplied until nearly 24 hours later.

After the water reached the 27-foot stage the city was practically cut off from the rest of the country. Railroad bridges were rendered unserviceable, and the telegraph companies would not promise to get a message off in any direction. The new bridge connecting Terre Haute with the town of West Terre Haute, on the other side of the river, was closed to traffic for two days, March 28 and 29. However, this bridge sustained only slight damage. On the west side of the river, the Vandalia and Big Four tracks were under water for a distance of a mile or more, and considerable damage was done railroad property in this place.

Fortunately, the city was not afflicted as were some other places on the river in having the water cut off. While the water company could not keep its water up to the standard, it did not find it necessary to close down.

The damage, inconvenience, and suffering resulting from the flood at Terre Haute, was experienced at all other places along the river. At Logansport, La Fayette, and Clinton bridges were washed away. At most places the water, gas, and electric plants were stopped, which, coupled with the other afflictions that came upon the people as a result of the flood, made the situation most acute.

At Logansport the bridge on which the Weather Bureau gage was installed was washed away, and the water rose to such a high point in this town that most of it was under water for a while. The rain gage was carried away, and also some of the records in the possession of the river observer.

The water, gas, and electric plants of La Fayette had to discontinue operations; the traffic on all steam and electric lines entering the city was suspended; the heating plant was closed; the fuel supply became exhausted, and one bridge was washed away and another condemned.

Peru was the most demoralized of any town in the Wabash Valley. At that point three persons were drowned, and the suffering was most intense. All public buildings were turned into commissaries or dormitories. The water rose so rapidly and high that it caught people in their places of business and elsewhere. The people in the town of Peru, and elsewhere in the valley, expected the water to reach only the usual flood stage, and consequently the flood proved disastrous to many who thought they were safe.

It is estimated that the property loss in the Wabash Valley will aggregate $10,000,000.

A REPORT ON THE FLOOD IN THE ILLINOIS RIVER IN MARCH, APRIL, AND MAY, 1913.

By MONTROSE W. HAYES, *Local Forecaster.*

A joint resolution of the Illinois Legislature, passed in May, 1889, relative to constructing a waterway from Lake Michigan to the Mississippi River, refers to the Illinois River in the following language:

> The Illinois River from La Salle to Grafton is the remnant of an ancient stream bed, bordered by wide and low bottom land, much cut up by lake, bayou, and marsh; and an alluvial stream of small low-water volume and sluggish current, with a declivity of only 26 feet in 225 miles, a declivity so small as to require a large volume of water to maintain an effective channel; a stream which in its natural condition is able to maintain but a small depth through the deposits with which the tributaries constantly tend to choke the channel, a tendency ever increasing with the inhabitation of the watershed and the cultivation and reclamation of lands.

It is quite probable that this alluvial stretch of the Illinois, which really begins at Utica, 6 miles above La Salle and 230 miles above Grafton, has less slope than any other stream in the upper three-fourths of the Mississippi River drainage area. It naturally follows, on account of the slight slope, that the run-off is slow and the gradual rises and falls cause the stream to remain out of its banks or bank full after other watercourses flooded by the same storms have fallen to normal stages.

The beginning of spring almost always finds the Illinois nearly or quite bank full, even though the winter precipitation may have been less than the normal. This is due to the effect of cold weather on the water flow. The river freezes over, friction caused by the ice covering decreases the discharge, and the fall in the stages is not proportional to the decrease in the tributary increment that follows the freezing of the small streams. When the ice begins to move the small slope causes it to gorge and still further decrease the discharge, and the tributary water released as the weather grows milder runs into a trunk stream that is almost or altogether full. It is evident, therefore, that the spring precipitation does not have to be especially heavy or long continued to give flood stages.

A study of gage readings, in connection with precipitation charts, shows that the stretch of river below the mouth of the Sangamon is, at high stages, influenced materially by the stage of the Mississippi at Grafton. (The Sangamon flows into the Illinois 98 miles above Grafton.) This influence, of course, is felt throughout the extent of the alluvial stretch, but above the mouth of the Sangamon it is not sufficiently pronounced to show itself in a casual investigation of the gage readings and precipitation charts.

In 1913 the precipitation over the Illinois watershed was about normal in January and somewhat less than normal in February. When March opened the river was bank full through most of the alluvial stretch, as is usual for the season, and frequent moderate rains caused a gradual rise until the latter third of the month, when the passage of a phenomenal procession of storms began. These storms were not productive of as much precipitation as they were in Indiana and Ohio and in that portion of Illinois drained by streams that enter the Mississippi

south of Grafton, but they were heavy enough to cause a rise to begin simultaneously in all stretches of the river. Rain fell on March 20 and 21, and from the 23d to 27th, inclusive. The combined amounts for the two periods ranged between 2 and 4 inches over the watershed above the mouth of the Sangamon and between 4 and 6 inches over the remaining or lower part of the watershed. The precipitation in the country, receiving between 2 and 4 inches, was noteworthy more because it was so general and uniform than because it was excessive. It was not nearly so heavy as the rainfall of September, 1911.

At La Salle the rise was comparatively rapid, as this station is only 6 miles below the upper extremity of the alluvial stretch, and the crest, 28 feet, occurred on March 29; but with the entire river from Utica to the mouth overflowing the fall naturally was much slower than the rise, and the stream was not within its banks until April 18.

At Peoria, 62 miles below La Salle and 162 miles above the mouth of the river, the highest stage was reached on March 30 and prevailed until April 2. Peoria is at the foot of Peoria Lake, which is a succession of three expanses of a total length of 17 miles, in which the river spreads in places to a width of a mile and a half when the stages are normal. This lake, as it is termed, has a reservoir effect that gives, even for the Illinois River, very gradual fluctuations in stage at Peoria. There was practically a continuous fall after the maximum, which was 22.3 feet, occurred, but it was the latter part of April before the stream was in its banks.

Beardstown is 135 miles below La Salle and 89 miles above the mouth of the river. At that station the highest stage was 21.8 feet which prevailed on April 5 and 6. The crest of the flood at Beardstown did not have the same form the crest at Peoria had, as it was materially changed by the volume of water contributed by the Sangamon River, which flows into the Illinois 9 miles above Beardstown. After the passage of the crest there were heavy rains over the lower part of the Illinois watershed, and the river was bank full at Beardstown until May 13.

This flood was an unusually high one, but none of the stages was unprecedented. Most of the conditions were favorable for a record-breaking high-water level, but one very important requisite was missing; that was a high stage in the Mississippi at the mouth of the Illinois. All of the floods that were greater than this one have been coincident with a flood in the Mississippi at Grafton, but at no time in the spring of 1913 was the Mississippi stage more than what may be termed bank full at Grafton, and on this account there was a good current in the Illinois even when the water was highest. This comparatively rapid discharge, it is believed, prevented the river from reaching a record-breaking height, at least in its lower reaches, where the influence of the Mississippi stages is most pronounced.

Levees broke at Hennepin, 208 miles above the mouth, at Meredosia, 71 miles above the mouth, and at Naples, 65 miles above the mouth. At Beardstown the levee protecting the Combes addition to the town broke. All of these breaks caused considerable property loss, and inconvenience and suffering to those who were compelled to abandon their homes. At Meredosia the Wabash Railroad crosses the river, and the railroad approaches or embankments were damaged to such an extent that traffic had to be suspended.

Along the entire alluvial stretch of the river the water was high enough to damage roadways of all kinds, bridges, buildings, etc., but the greatest damage was on agricultural lands. The tributaries were carrying a large volume of water which could not be discharged and cross levees were washed out or damaged. Considerable corn had been left in the field and most of this was lost. Some farm buildings and machinery were damaged or entirely ruined, and some wheat was lost by being covered by water; however, from the reports received, it is not thought that the loss to growing crops was large.

The slow fall of the flood water caused considerable anxiety to farmers; it was feared that the ground could not be put in condition soon enough to enable a crop of corn to be put in, and in most sections along the river the planting was, necessarily, late, but not too late for the crop to give a good yield, provided favorable weather prevails during the remainder of the season.

There was no direct loss of life in the flood; that is to say, the Weather Bureau correspondents along the river reported none, and no newspaper accounts of any were seen. Many families were driven from their homes by breaks in the levees, or overflows, or through fear of the water coming in, and it is quite probable that there were deaths from exposure, which should be termed deaths caused by the flood, but there appears to be no way of obtaining statistics of this. In fact, all the statistics of losses are quite unsatisfactory, and in reality mean very little. To obtain figures that could be considered authentic, as well as complete, would be an expensive and tedious task, probably out of proportion to the value of the information. And when the losses in Illinois are compared to those in Indiana and Ohio they become so insignificant they are of minor importance.

THE FLOOD IN THE OHIO, IN THE LOUISVILLE DISTRICT.

By F. J. WALZ, *Professor of Meteorology.*

The flood was caused by excessive rains over the entire drainage basin during the period March 23–27, 1913. The rainfall was much greater over the drainage areas of the northern tributaries of the Ohio than over the southern tributaries of that stream, the reverse of the distribution that produced the floods in January last. The flood waters, therefore, in the smaller streams and in the main tributaries flowing through Kentucky, except over the Kentucky River section, were not so high or so destructive as they were in January. The heaviest rains in Kentucky, 6 to 7 inches, fell over the upper watershed of the Kentucky River, most of it in about 48 hours, hence the greater flood in that stream in comparison with other streams in the State. Also between 6 and 7 inches of rain fell in about the same period of time over the upper watershed of the Cumberland and Barren Rivers, causing floods of large proportions in sections of those streams. In other than the above-mentioned sections, the flood damage, while large, was not extraordinary except from the overflow of the Ohio River itself. Away from the Ohio, while damage to property runs high yet there was comparatively little suffering or distress and losses were mostly from interruption to traffic and business.

(The daily amounts of precipitation that occurred over Kentucky during the period Mar. 23–27, 1913, will be found in Table 2, p. 22.)

At Pikeville, Ky., on the Big Sandy River, the crest of the flood was reached at 2 p. m., March 27, 39 feet. At Louisa, Ky., on the same stream the crest was reached at 12 noon March 28, 44.8 feet. While this stage is 15.3 feet higher than the stage reached in January, the location here is such that stages in the Big Sandy above 20 feet are due almost entirely to backwater from the Ohio River.

At Falmouth, Ky., on the Licking River, a crest of 34.1 feet was reached at 1.30 p. m. March 27. This was 0.3 foot below the reading reached January 12, 1913.

At Rumsey, Ky. (Lock No. 2), on the Green River, the flood in January reached a crest of 35.5 feet, while the highest reached in this flood was 31.2 feet, April 5.

At Burnside, Ky., on the upper Cumberland River, the crest reached in January and that in March were exactly the same, 61.5 feet. The high flood stage reached at Burnside in the March flood was due to the fact that the northern headwater tributaries of the Cumberland drain an area visited by the heavy rains which also extended over the upper tributaries of the Kentucky River.

KENTUCKY RIVER.

The Kentucky River was above flood stage (30 feet) at Beattyville on two days, the 27th and 28th, reaching a crest at 2 a. m. of the 28th of 39.9 feet which is 7.9 feet above the January stage. The estimated damage in Beattyville and vicinity is only about $5,000 from all causes. The money value of property saved by moving and protection is about $10,000.

At High Bridge the Kentucky River was above flood stage (27 feet) from the 27th to the 31st, inclusive, and reached a crest of 34.6 feet on the 27th. This is 1.6 feet above the crest reached in January. The damage was inconsiderable, in fact about $1,000, mostly from

loss of saw logs which were carried away. The flood stage at High Bridge has since been raised to 30 feet.

At Frankfort the Kentucky River was above flood stage from the 27th to 31st, inclusive, and reached a crest of 38.3 feet at 5 a. m. on the 28th, which was 4.5 feet above the crest of January 12, 1913. The highest water known at Frankfort, 44.5 feet, occurred in February, 1878. The waterworks pumps at Frankfort were again put out of commission, and there was some inconvenience and suffering from the water famine; also there was considerable damage from landslides on steep banks in that vicinity. Train service was interrupted for a few days, otherwise the damage there was inconsiderable and not any greater than in January last. Flood warnings were issued to the river observer at Frankfort, beginning with the 26th, and from there widely distributed by telephone, and also through the Louisville newspapers which circulate largely in all parts of the State. These warnings enabled a number of families to leave their homes and remove their belongings before the water reached them.

OHIO RIVER.

At Madison, Ind., the river was above flood stage—46 feet—from the afternoon of March 26 to the early morning of April 8. The crest of the flood reached a stage of 62.8 feet, which is the highest on record and was 1 foot above the record of February, 1884. This was the only station in the Louisville district on the Ohio River where the stage of 1884 was exceeded and was no doubt due to the coming together of the extraordinary flood waters of the Great Miami and those of the Kentucky. At Cincinnati, Ohio, a crest of 70 feet was reached, which is 1.1 feet below the crest of the 1884 flood.

At Louisville, Ky., a crest of 44.9 feet was reached about 2 a. m. of April 2, which is 1.8 feet below the 1884 flood crest. Here the Ohio River was above flood stage from the afternoon of March 26 to the early morning of April 9. For the second time this year the river completely submerged Shippingport, a small section of the city lying between the river and the Louisville and Portland Canal and containing 78 families, also a section of the city below what is known as the "cut-off," where some 1,700 families were rendered homeless. The flood water spread over quite a large area bordering on the river, including a part of a section known as Parkland and sections along Bear Grass Creek. The backwater up this creek flooded several of the principal streets, inundating bridges, which caused a disarrangement and partial suspension of street-car and other traffic. Also, there were a number of factories and mills of various kinds that were flooded and had to suspend business for a week or ten days at considerable loss. A large whisky warehouse containing 3,690 barrels of whisky collapsed on account of being undermined by high water, and the barrels of whisky were plunged into the river. Most of them were finally recovered.

Railroad and mail services were badly hampered. All roads from Louisville to Chicago, except the Chicago, Indianapolis & Louisville Railroad (Monon), had to suspend business, and all train service ceased for several days on lines leading north and east except the Louisville & Nashville to Cincinnati. Roads from Louisville to St. Louis also suspended train service for several days.

In Louisville and vicinity it is estimated that 2,000 persons were thrown out of employment on account of the flooding of factories. Damage to factories and business houses in the flooded district together with the loss in wages and from suspension of business is estimated at half a million dollars. River navigation was practically suspended on account of the high water making it impossible for the larger boats to pass under the bridges. The Union Railroad Station at the foot of Seventh Street was abandoned March 30, the water being over the tracks and in the lower story of the building, and all the railroad yards on the river front were for the most part under water for about a week.

The city authorities were advised well in advance of the overflow and inundation of the two sections of the city where danger was greatest, namely, Shippingport and the Point

(or section below the "cut-off"). As the flood waters were coming on so rapidly the mayor was advised by personal call over the telephone to get the people out of those sections without any delay or loss of time. With the aid of the police and fire departments all the families and their household goods were removed to places of safety before the flood waters enveloped their homes.

One of the most critical and dangerous situations developed by the flood was the condition at Jeffersonville, Ind., across the Ohio River from Louisville, Ky. The city is protected by a levee in front and by an embankment or fill under the tracks of the Pennsylvania Railroad at the lowest point between the city and New Albany. The levee was not high enough to resist the stage of 45 feet and was strengthened at many places with bags of sand, cement, dirt, etc.; while across several of the streets where the levee was low, timber barricades were built and filled in with dirt to bring the height above the expected crest stage. But the hardest struggle was necessary at the Pennsylvania fill. As the water rose at this point the embankment began to slip away and leak. Electric lights were strung along the fill and a guard established; also about 200 of the convicts at the Indiana reformatory, a few hundred feet away, were pressed into service, and with their help about 170,000 sacks of sand and cement, great quantities of dirt and other material were used to reenforce and strengthen the weak places, the fight going on both day and night until the crest was passed and the water receding. About 100 tarpaulins were loaned by the Jeffersonville depot of the Quartermaster's Department and were spread on the side of the fill next the river, materially assisting in preventing the water from cutting through the embankment. If this fill had broken, nearly every business house in the city and probably 2,400 homes would have been flooded, with enormous damage. On account of the close proximity of the local office of the Weather Bureau the city officials and citizens were able to obtain warnings at all times and made their desperate fight against the rising waters on the basis of the information furnished. The loss to property located outside the district protected by the levee is estimated at about $40,000, and as that part of the city is relatively small it is estimated that the value of property saved by the work on the levee and fill is at least $1,000,000.

Flood information and warnings were issued from the Louisville office from time to time, beginning March 26, 1913, of which the first and last only are given below:

March 26 (10 a. m.).—Excessive rainfalls, ranging in amount from 2 to 5 inches and more, have fallen during the past 24 hours over the entire watershed. The river has risen 21 feet since yesterday morning at Cincinnati, and is now above flood stage at that point. It had risen 16 feet at Madison and nearly 11 feet at Louisville at 7 a. m., and 2 feet at Louisvile from 7 to 10 a. m. It is now rising at the rate of nearly one-half foot per hour. It will pass the flood stage early to-night and continue rising rapidly during several days.

Special bulletin (9 p. m.).—At 7 p. m. the river stage at Cincinnati was 54.8 feet and rising at the rate of three-tenths of a foot per hour. It was rising steadily above Cincinnati, but in the stretch from Catlettsburg to Maysville it was 15 to 20 feet below flood stage, while at Pittsburgh it was 3 feet above flood stage. At 9 p. m. the stage at Louisville was 30 feet, and the river was rising at the rate of five-tenths of a foot per hour. A stage of near 33 feet or more is expected by 7 or 8 o'clock Thursday morning. It will continue rising during Thursday, but the rate of rise will probably decrease somewhat, and from present indications the crest will be between 35 and 36 feet at Louisville.

April 7, 1913.—The river this morning has passed below the flood stage at Maysville and was only 0.5 foot above that stage at Cincinnati, where the fall since Saturday morning has been nearly 13 feet. The decline in this section will from now on be rapid.

The bulletins were given wide dissemination through the local press and over the telephone. In addition a bulletin giving the river stages at the various stations reporting, at stated times, was issued daily in postal-card form and mailed to persons interested. This bulletin also contained a statement as to expected heights as far as they could be anticipated. Thousands of inquiries were received over the telephone, many of them long distance. In fact, at points from the mouth of the Kentucky River to Tell City, Ind., a distance of nearly 200 miles, the people were kept directly informed and warned through the medium of the telephone.

It is needless to say that the services of the Weather Bureau proved of inestimable value to the flooded sections and those threatened by flood. Many commendations of the value and accuracy of the warnings and forecasts have been received.

OHIO FLOOD—EVANSVILLE, IND., DISTRICT.

By AL. BRAND, *Local Forecaster.*

Continued heavy rains over most of the Ohio and its tributary valleys during March 24, 25, 26, and 27 started a rapid rise along this stretch of the Ohio River on March 25 from stages ranging between 24 and 27 feet. Within 48 hours after the rise began flood stages were reached and passed at Evansville, Henderson, and Mount Vernon, and devastating, record-breaking flood conditions prevailed in most of the Evansville River district from March 26 to April 18, inclusive.

At Evansville, Ind., the rise began on March 25, from a stage of 26 feet. The rise was especially rapid during the first 48 hours, amounting to 10.6 feet; river reached and passed the flood stage, 35 feet, sometime during the hour ending at midnight of March 26. The greatest 24-hour rise, 6.5 feet, occurred during the period ending at 7 a. m., March 27. From 7 a. m., March 27, to 7 a. m., April 1, inclusive, the 24-hour rises diminished gradually from 3.8 feet to 1 foot. After 7 a. m. of April 1 the 24-hour rises were less than 1 foot until about 9 a. m. of April 3, when the river came to a stand with the gage indicating a stage of 47.9 feet; river remained stationary at a stage of 47.9 feet until shortly after 12 noon of April 3, when a second creeping rise set in as a result of a heavy rain which had set in over this section of the Ohio and Green River Valleys, combined with a fresh to brisk wind blowing directly onto the gage. The second rise terminated shortly after 12 noon of April 5, with a crest stage of 48.3+ feet. This crest stage of 48.3+ feet is the highest stage ever recorded at Evansville in the history of the station. River remained stationary at 48.3+ feet until about 6 p. m. of April 5, when it began to fall slowly; the slow fall, amounting to less than 1 foot in 24 hours, continued until 7 a. m. of April 10, after which the 24-hour rate of fall increased slowly, but gradually, from 1.4 to 2.5 feet; river was falling at the latter rate when it dropped below the flood stage, 35 feet, at about midnight of April 15. Since that time the river has continued falling at a rate averaging slightly over 1.5 feet in each 24 hours.

At Henderson, Ky., where the rate of rise and fall was again very similar to that experienced at Evansville (the greatest 24-hour rise, 6.5 feet, being the same and occurring on the same date as that at Evansville), the rise started on March 25 from a stage of 24 feet; river reached and passed the flood stage, 33 feet, shortly before daybreak of March 27; river came to a stand during the afternoon of April 5, with a crest stage of 47.9 feet. The crest at Henderson was, it is believed, materially raised by backwater from the Wabash. River remained stationary at Henderson with a stage of 47.9 feet until sometime during the night of April 5 and 6, when it began to fall slowly; river fell below the flood stage, 33 feet, at 11.30 a. m., April 16.

At Mount Vernon, Ind., the rise began on March 25, from a stage of 26.3 feet. During the first 24 hours ending at 7 a. m., March 26, the rise amounted to 2.7 feet, while the greatest 24-hour rise, 5.3 feet, occurred during those ending at 7 a. m., March 27. River reached and passed the flood stage, 35 feet, at 11 a. m., March 27. From 7 a. m., March 27, to 7 a. m., March 30, inclusive, the 24-hour rises gradually diminished from 3.9 to 2.7 feet. As a result of the destructive flood wave which began surging into the Ohio from the Wabash during the night of

March 29 and 30, the rate of rise at Mount Vernon again increased quite suddenly during the morning of March 30, due to backwater, and amounted to 3.5 feet during the 24 hours ending at 7 a. m. of March 31; after this time the rate of rise diminished materially, the river coming to a stand at 9 a. m. of April 5, with a crest stage of 52.9 feet, scant. River remained stationary at a stage of 52.9 feet, scant, until sometime during the night of April 6, when it began to fall slowly; the 24-hour rate of fall amounted to less than 1 foot until after 7 a. m., April 10, when it increased gradually from 1.7 to 3.5 feet; river was falling at the latter rate when it dropped below the flood stage, 33 feet, at 4 a. m., April 18. Since falling below the flood stage, the decline has continued steadily, mostly at a decreasing rate.

ACTION BEFORE AND DURING FLOOD.

The first reference to the rapid rise expected along this stretch of the river was made in the regular river forecast published on March 25, which read as follows:

The Ohio.—As a result of the heavy rains during the past 48 hours, a rise will set in at Evansville, Henderson, and Mount Vernon this afternoon or to-night. The rate of rise will increase rapidly during the next 48 hours. Sufficient water now in sight to raise the present stages in the lower part of the Evansville district 3 or 4 feet by Wednesday night or Thursday morning.

At 8.40 a. m. on March 26 (Wednesday), the following flood warning was issued by the official in charge of the local office and disseminated as widely as possible throughout the Evansville River district by means of the local press, river bulletins, telegraph, and telephone:

Flood warning.—Stages of 35, 33, and 35 feet will be reached and passed at Evansville, Henderson, and Mount Vernon, respectively, Wednesday night or Thursday morning. Notify interests.

From time to time additional warnings were issued as conditions of the weather demanded. Only the initial and final warnings are here given. The latter, under date of April 4, 1913, follows:

April 4.—The Ohio River continues falling at all upriver points. The rain during the past 24 hours, combined with backwater and brisk wind, has caused additional slight rises on all gages in the lower part of the district. While the river is now on a stand at Evansville, additional rises of a tenth or so may occur at these points due to the rain, backwater, and wind. At Mount Vernon it will come to a stand to-night or Saturday morning, with a stage of about 53 feet.

In addition to the flood warnings and river forecasts published and distributed by every possible means from day to day, the official in charge of the local office furnished by telephone and telegraph advisory and timely information to all applicants from outlying districts and neighboring river towns; when the water began to encroach upon Water Street he also personally called on the merchants on that street and advised them to make use of splashboards and sand bags in order to keep the water from getting into their basements and first floors.

The March-April, 1913, flood was, at least in the lower part of the Evansville River district, the greatest and also the most devastating flood in the history of this station, as well as in the memory of the oldest inhabitant. All of the lowlands and most of the river towns and cities in the district contributed toward making up the enormous losses experienced in the Ohio Valley from Louisville, Ky., down to the mouth of the Wabash River. The flood water rendered homeless thousands of people and made prisoners of many others in their homes for days, in some instances without food. Thousands of buildings, consisting of houses, barns, outbuildings, tool sheds, corncribs, etc., with most of their contents, were completely washed away, while a great many that were left were thrown or moved from their foundations or otherwise disarranged; hundreds of thousands of bushels of corn and immense quantities of cured hay and other foodstuffs were lost, and large tracts of growing wheat, clover, timothy, etc., were completely destroyed. Some, in fact most all, of the rural districts were deprived for days of all means of outside communication, while some of the smaller river towns were without mails for a week or 10 days. Enterprise, Tell City, and Cannelton, Ind., and Hawesville and Uniontown, Ky., were, it is believed, the heaviest sufferers among the towns affected by the flood in this district.

At Enterprise, Ind., a small village, all the inhabitants, 30 families, or about 120 people, were driven from their homes, as every house was more or less flooded.

At Tell City, Ind., a thriving and prosperous manufacturing town, with a population of about 4,000, all of the factory district as well as a large portion of the residence section was flooded, and about 300 families were compelled to abandon their homes.

At Cannelton, Ind., and Hawesville, Ky., two small towns on nearly opposite sides of the river, each with a population of about 1,000, the greater portion of each town was flooded, and about 75 families of each place were required to seek temporary homes elsewhere.

At Uniontown, Ky., 13 miles below Mount Vernon, Ind., and about 6 miles above the mouth of the Wabash River, with a population of about 2,000, where the suffering, as a direct result of the flood, is believed to have been infinitely worse than at any other point along the Ohio, not excluding Shawneetown, Ill., every house in the city was flooded to such an extent as to make it absolutely uninhabitable, and all residents were compelled to leave their homes and seek shelter at the fair grounds, back on the hills. A member of a relief party sent out from this city (Evansville) stated that the actual suffering at Uniontown during the first three or four days after the residents of that place were compelled to leave their homes was indescribable; rich and poor alike were compelled by necessity to huddle together in stalls and in such other improvised shelters as were offered by the flimsy and insecure structures at the fair grounds, without the necessary food, bedding, or clothing.

The publisher of the Telegram at Uniontown, Ky., states that the losses to city property at Uniontown, Ky., will amount to at least $200,000; that there was a loss of about 60,000 bushels of wheat and about 75,000 bushels of corn in that immediate vicinity, and that the losses occasioned by enforced suspension of business, including loss of wages by employees, were estimated to amount to another $50,000.

At the present market value of wheat and corn the losses at Uniontown, Ky., and vicinity would in the aggregate amount to fully $336,500. The publisher of the Telegram also stated that—

> Possibly half of this loss would have been avoided if the people had heeded the warnings sent out by the Weather Bureau. Most of the people prepared for an 1884 water only, and when the crest reached 27 inches higher the greatest part of the damage was suffered.

From information obtained from other sources it appears that most of the residents of Uniontown, Ky., notwithstanding the warnings sent out by the local office, Weather Bureau, Evansville, Ind., believed that they would be able to escape flood water by scaffolding about 1 inch higher than what would have been necessary to escape the last January water. As a result the upriver water, reenforced by the flood wave which began surging out of the Wabash during the night of March 29–30, caught them unprepared for the sudden rise which occurred at Uniontown on March 30 and 31. The sudden rise, due largely to backwater from the Wabash, prevented the removal of the merchandise in the stores, as well as the furniture, etc., from the houses; it also prevented rescaffolding of same to raise it above flood water. The losses resulting from the flood will be a serious blow to the merchants of Uniontown.

The main cause of the destructive flood wave which swept things clean throughout the lower White and Wabash Valleys on March 28, 29, and 30 appears to have been the breaking away of about 1,400 feet of the Chicago & Eastern Illinois Railroad embankment, located in the White River Valley, between Decker and Hazelton, Ind., and about 18 miles above the mouth of the White River. This embankment, which is about 4 or 5 miles long, acts as an immense dam in times when the White River is in flood; in consequence of this, when it broke late Friday afternoon or evening, March 28, a perfect wall of water was suddenly released and allowed to sweep everything before it in the lower White and Wabash Valleys.

At Evansville, Ind., the flood caused but little damage but considerable inconvenience. All of the main portion of the city was high and dry, the only districts flooded being those along the eastern and southeastern edges of the city known as Oakdale, Crofton Place, Maple Place, Maple Grove, and Garden Acres; some of the low-lying sections along Pigeon Creek, and

Water Street, between Vine and Locust Streets, were also flooded. The suburb of Oakdale, which is believed to be the lowest section of the city, is composed of 400 or 500 modest houses, averaging in value between $900 and $1,000, and begins to flood when the river passes the 42-foot stage on the local gage. When the water was at the maximum stage the flooded districts along the eastern and southeastern edges of the city, as well as those along Pigeon Creek, were flooded to a depth ranging between 2 and 6½ feet, the latter depth being confined almost entirely to the lowest sections of Oakdale. At a stage of 46.5 feet the water begins encroaching upon Water Street adjoining the public levee. When the flood was at its highest all of the business portion of Water Street, between Division and Locust Streets, was flooded to a depth of about 6 inches, the water reaching almost to the top of the curbing along the outer edge of the sidewalks; some of the merchants along this street made use of splashboards and sandbags to prevent the water from being splashed into their first floors and cellars by the high wind. All railroads and some of the suburban electric lines entering this city, as well as the city street car lines in outlying sections, were seriously interfered with; all of the railroads, except those leaving and entering the city by way of the Louisville & Nashville Railroad Bridge, were compelled to suspend all through business to northern, eastern, and western points. This interruption in railway traffic, which was general throughout most of the States bordering on the Ohio River, had a far-reaching effect, as it continued for about two weeks, and brought about an unusual sluggishness in all lines of trade in every city in this district; it also interfered to a great extent with the prompt movement of mails throughout all of southern Indiana.

The flood caused but little damage at Mount Vernon, Ind., and at Henderson, Ky., as both of these towns are located well above the flood line; they were, however, affected and inconvenienced by the interrupted mail and railway services.

Local, State, and Federal aid in the way of tents, food, clothing, medicine, and feed for live stock was furnished to flood refugees at nearly all towns and cities in this district.

Very little drift was left on the lands flooded, and most of the bottoms that were overflowed were materially benefited by a deposit of silt in the nature of a rich loam, ranging between 2 and 6 inches in depth. Spring plowing, it is believed, was not delayed by the flood.

FLOOD IN THE MISSISSIPPI RIVER, APRIL, 1913, CAIRO, ILL., TO HELENA, ARK.

By S. C. EMERY, *Local Forecaster.*

Following the rise in the Mississippi River that culminated on February 3, with a stage of 40.5 feet on the Memphis gage, the river fell rapidly, reaching 16.1 feet at New Madrid on February 26 and 17.3 feet at Memphis on February 27. Then, as a result of heavy rains in Tennessee and Kentucky and general though moderate rains over the northern watershed of the Ohio River during the last two days in February, the morning reports on March 1 showed rising stages in the Ohio River from Pittsburgh to Cairo and in the Mississippi from St. Louis to Memphis. In this district the total increase on river stages, due to the rains above mentioned, was about 9 feet, the rise occupying the period March 1 to 10. This rise did not greatly affect the lower reaches of the Mississippi River, the increase at Vicksburg being only 1.4 feet, but inasmuch as they had not then regained normal conditions following the February rise it caused the abnormal stage to be sustained until the arrival of the southwest storm that swept over this section on March 26 and 27, attended by a heavy downpour of rain that caused an additional rise that continued until the Ohio flood waters began to enter the Delta country. In other words, the lower river was well filled before the real flood entered the head of the valley, a condition that usually attends all severe floods in the lower Mississippi.

On March 15 the rise that had been in progress in the upper Mississippi and Missouri Rivers for some days began to be felt at Cairo, and, being augmented by a heavy downpour of rain an March 14, the rise was very rapid, as much as 15 feet being added to the Cairo gage in eight days.

At Memphis the rise began on March 18, with a stage of 20.7 feet, and in the next eight days 11 feet was added to the gage reading. At Helena the stage increase in the first 11 days was 14 feet. Flood stage (35 feet) was reached at Memphis on March 30, the increase in 13 days being 14.8 feet. The rise in the lower river up to this time was caused by a storm that passed northeastward over the Central Valley region on March 13 and 14, causing heavy rains and snows in the Missouri and upper Mississippi watersheds and general rains in the Ohio Valley from below Pittsburgh to Cairo. The principal flood waters from the Ohio River, those caused by the remarkable rainfalls in the States of Indiana and Ohio and which resulted in severely inundating several cities in those States, had not yet reached as far south as Memphis. After reaching flood stage at Memphis the rise was less rapid for a day or two, but when the first effects of the Ohio flood began to be felt the rate of rise increased to over a foot per day, and on April 7 reached 44.9 feet. At 8 a. m., April 8, the river stood three-tenths of a foot above the record for 1912, which was 45.3 feet. On the following day, April 9, four-tenths of a foot had been added to the Memphis gage, and at 7 a. m., April 10, the gage reading was 46.5 feet, with indications that a very slight fall had occurred between 5 a. m. and 7 a. m., estimated at less than a tenth of a foot. This stage, 46.5 feet, is 1.3 feet above the 1912 record and 9.4 feet above that of 1897, which up to that time was the greatest flood on record. A further rise at Memphis was prevented by a break in the levee at 5.30 p. m., March 9, at Golden Lake, Ark., 38 miles by river above Memphis, and near the scene of the Wilson break in 1912. Also by a break in the levee near Graves Bayou, Ark., 23 miles below Memphis. The latter occurred at 2 a. m., April 10, and was the direct cause of the fall shown on the Memphis gage of 1.8 feet on April 11. Following this decided drop, the next seven days showed a decline of less than

2 feet. At the time the breaks in the levee occurred the river at Memphis was rising at the rate of about one-half foot per day, and notwithstanding the fact that Cairo had reported a stationary or falling stage during the six preceding days the river continued rising at Cottonwood Point, Mo., 116 miles above Memphis, up to the 10th, and on the same day at Fulton, Tenn., 57 miles above Memphis, showed a rise of one-tenth of a foot, and the next day, April 11, a fall of seven-tenths of a foot, which fall was clearly due to the break in the levee at Golden Lake, 20 miles below. From the fact that rising stages continued at all points south of New Madrid, Mo., until the levee gave way it is fair to assume that had no break occurred the river at Memphis would have continued rising at least two or three days longer and carried the stage to 47.5 feet. The conditions affecting the stage of the river at Cairo in 1913 were practically the same as obtained in 1912; that is, the levees in that vicinity broke in the same places, and yet with only eight-tenths of a foot increase in stage height above 1912 at Cairo the gage at Memphis showed 1.2 feet more in 1913 than in 1912. This may be accounted for in part by the fact that only one break in the levee occurred below Wilson, Ark., this year against two in 1912, namely, St. Clair and Wyanoke.

At New Madrid, Mo., the river reached flood stage, 34 feet, March 27, and the crest stage, 44.5 feet, April 9. It was above flood stage 30 days, and above 40 feet 21 days. In 1912 it was above flood stage 34 days and above 40 feet 23 days.

At Memphis the river reached flood stage on March 30, and the crest stage, 46.5 feet, April 10. It was above flood stage 30 days, and above 40 feet 20 days. In 1912, it was above flood stage 56 days, and above 40 feet 23 days.

At Helena it reached flood stage on April 1, and the crest stage, 55.2 feet, April 21. It was above flood stage 34 days, and above 50 feet 24 days. In 1912 it was above flood stage 62 days, and above 50 feet 29 days.

The 1912 record was exceeded at New Madrid, Mo., 0.5 foot; Memphis, 1.2 feet; Helena, Ark., 0.8 foot.

The long continued rise at Helena was due to the water that escaped through the several breaks in the Arkansas levee, returning by way of the St. Francis River which joins the main stream 8 miles above Helena, Ark. Conditions somewhat similar obtained at New Madrid where the river rose for five days after it became stationary at Cairo and showed no material change for six days thereafter, 11 days in all. This was caused by the overflow water from breaks in levees opposite and above Cairo passing south via St. Johns Bayou and the swamp region in southeast Missouri and rejoining the Mississippi above New Madrid.

A matter of special interest in connection with floods in the section of the river between Cairo and Helena is the change in gage relation between Cairo and stations north of Helena. At the time of the great flood of 1882, the excess in gage height at Cairo, above Memphis, was 16.8 feet, this being near the average difference between the two gages previous to the construction of the protecting levees in this district. In 1897 this difference was reduced to 14.5 feet; in 1903, the difference was 10.5; in 1907, 10; in 1912, it had dropped to 8.7 feet, and in 1913, to 8.2 feet. While it is possible that had no break occurred in the levee, the river at Memphis would have reached a foot higher than it actually did, it is equally possible, had no break occurred at Cairo, that gage would have indicated a higher stage, therefore it seems probable that under present conditions the difference between Cairo and Memphis will continue close to 8 feet.

At Helena the effect of levee construction in Mississippi was first seen in 1897, when the difference between that station and Cairo was changed from -4.6 feet to $+0.2$ feet, an elevation of the flood plane of practically 5 feet. Since that time Helena has ranged from one to five-tenths above the Cairo reading.

Crevasses.—On March 31, at 5 p. m., the levee at Columbus, Ky., gave way and caused that city to be flooded to a depth of from 5 to 10 feet. As all hope of saving the levee had been abandoned early in the day, the people were warned to leave and as a result only a few families remained when the flood waters entered the town.

On April 4, at 12.40 p. m. the levee protecting West Hickman, Ky., gave way and in an hour and a half all of that portion of Hickman was flooded to a depth of from 4 to 15 feet. In hundreds of houses the water reached to the top of the windows and every store building had water halfway to the ceiling. About 2,000 residents of the city took refuge on the high ground near by.

On April 5, at 8 a. m., a portion of the levee in North Memphis bordering Bayou Gayoso gave way and later on other portions of the same levee went out, resulting in severely flooding about 20 city blocks and drove 1,000 or more families from their homes and caused many of the manufacturing concerns to close. Owing to the alertness on the part of the city officials in warning people in the threatened district, there was no loss of life, and much valuable property was saved.

On April 9, at 5.30 p. m., the St. Francis levee near the town of Wilson, Ark. (at a place called Golden Lake), broke after two weeks of the most persistent high-water fight on record. At the time the break occurred the water was splashing over the sandbag topping at intervals of 500 feet for about three-fourths of a mile. Following this break, another occurred at Random Shot, 4 miles below Golden Lake. This occurred at about 11 p. m., April 9.

On April 10, at 2 a. m., a break occurred in the Arkansas levee near Graves Bayou, Ark., 23 miles below Memphis. The two breaks in the levee near Wilson, Ark., and the one at Graves Bayou, relieved the strain on the whole St. Francis system and prevented breaks in other portions of the levee that at the time were in great danger. The waters escaping through these crevasses, as they moved southward through the St. Francis River and the bayous and swamps draining into it by which they would eventually reach the Mississippi River near Helena, flooded to some degree parts of seven counties in Arkansas. The northeastern portion of Crittenden County was saved from overflow from the Wilson breaks by a low ridge near its northern boundary. This entire county was inundated in 1912. The eastern portion of Mississippi County, Ark., was also saved from overflow, but with these exceptions, the inundation in that portion of the St. Francis Basin lying in Arkansas was as complete as in any previous high water in recent years. The counties of Poinsett and Cross suffered severely, the water being from 2 to 3 feet higher in some sections than in 1912, while in St. Francis, Lee, and the greater portion of Crittenden Counties the flood was about one-half foot below 1912. The St. Francis River at Madison, St. Francis County, Ark., came to a stand on April 22 at a stage of 40.9 feet, which is 0.9 foot below the 1912 record at that place.

The St. Francis levee district, which comprises the St. Francis Basin proper, extends from Point Pleasant, Mo., southward to Helena, Ark., being bounded on the east by the Mississippi River and on the west by Crawleys Ridge. In this district there are 3,200 squares miles subject to overflow, 2,500 square miles being in Arkansas and 700 in Missouri. It is estimated that 75 per cent of the Arkansas lands in this district subject to overflow were flooded, and those located in Missouri comprise about 20 per cent of the 700 square miles, making a total in the St. Francis Basin of 2,015 square miles of flooded land. This is about 705 square miles less than in 1912.

The overflowed territory in Missouri from the high ground near New Madrid, Mo., to about opposite Cairo, Ill., comprises 439 square miles, making a total area on the right bank of the Mississippi River, between Cairo and Helena, directly flooded from that stream of 2,454 square miles, an area 400 square miles greater than the State of Delaware. Fortunately at the beginning of the flood period the St. Francis River was at a low stage, which permitted much of the overflow water from the upper districts to be carried off before the crevasses lower down occurred. Then again the recently constructed drainage canals in the northern portion of the basin aided materially in carrying off the waters, especially those that found their way into the basin through the crevasses in the vicinity of Cairo. Considering the great volume of water that entered the St. Francis Basin the land was cleared in a remarkably short time. Before the end of April farming operations were well under way in most of the northern counties, and by May 5 practically all portions of the basin were free of water.

Flood warnings.—On March 26 the public was advised by a special warning issued by the local office of the Weather Bureau to prepare for a severe flood, and the statement was made that a stage exceeding 40 feet was certain at Memphis, and that the stage at Helena would exceed 50 feet. On the following day, March 27, the following bulletin was issued and widely distributed throughout this district:

The river at Memphis will reach flood stage (35 feet) by Saturday or Sunday, and 40 feet in the next five or six days. The water now in sight is sufficient to give Memphis considerably more than 40 feet, and it is possible the maximum stage may approximate the 1912 record of 45.3 feet. At Helena a stage considerably above 50 feet is indicated.

Immediately following the publication of these warnings the several levee boards, Government engineers in charge of river improvement under the Mississippi River Commission, and the city of Memphis began to prepare for the expected flood. The writer of this report can confidently state that during no previous flood period during the past 20 years or more have the preparations for a high-water fight been as carefully planned or more successfully carried out than during the flood of 1913. Much credit is due Maj. E. M. Markham, in charge of the first and second districts, Mississippi River Commission, and his assistants, and Mr. B. G. Covington, chief engineer for the St. Francis levee board, in holding the levees intact when the river had reached a stage from 1 to 2 feet above the grade they were intended to withstand, and in not relaxing their efforts until all danger had passed.

As soon as this office announced that the flood would probably approximate the one that occurred in 1912, the St. Francis levee board immediately dispatched crews of men to Wilson, Ark., to strengthen the levee at that place, a crevasse having occurred there in 1912, and a weakness had developed during the January rise of this year. Also men and teams were distributed at convenient localities along the entire line. Government steamers and quarter boats were ordered assembled and supplied with stores, bags, and other material in order to be ready for an emergency call. In Memphis every available man in the city service was set at work strengthening and enlarging the levee bordering Bayou Gayoso. This levee is for the protection of north Memphis from back water in Wolf River, which in turn causes the bayou to overflow and flood that portion of the city whenever the Mississippi reaches a stage of 40 feet or over on the Memphis gage. At this time telephone and telegraph messages were pouring into this office from all directions and in great numbers. Many of these messages contained requests for information in regard to the advisability of moving stock and other property from certain localities; others inquiring the date the river would reach a certain stage in order that they could arrange for moving before the water reached them. Railroad officials, both in Memphis and in distant cities, sent in requests to be daily advised as to conditions in this district and future prospects.

On April 2 an additional warning was issued that the river at Memphis would reach 46 feet, and 55 feet or over at Helena. As the North Memphis levee was built to withstand only 42 feet on the Memphis gage, the city engineer department was strongly advised to prepare for 46 feet in the next 10 days. Accordingly hundreds of men and teams were set at work in night and day shifts in an effort to raise the levee to the proper grade. The Memphis Light & Power Co. and the Memphis Gas & Electric Co. began raising their private levees to higher levels. On April 7 the prediction was made that the stage at Memphis would exceed 46 feet, the amount depending on the stability of the Arkansas levee. On April 11 the city of Helena was advised that the maximum stage at that place would be 55.5 feet. The levee at that place had been raised to a grade that it was thought would stand 56 feet. On April 22 the river at Helena came to a stand at a stage of 55.3 feet, 0.2 of a foot below the estimate made 11 days previous.

Owing to the fact that the water along the Arkansas front was somewhat above the stage the levees were built to withstand, and in several long stretches the water was being held back by bags of sand, it was not possible to make an exact forecast as to the ultimate height of the flood at Memphis. However, the estimate of 46 feet made on April 2 was given 8 days in advance of the crest stage of 46.5 feet, and with the estimate of 45 feet 12 days in advance gave the people reasonable time in which to prepare for the coming flood.

REPORT ON FLOODS OF 1913—VICKSBURG RIVER DISTRICT.

By WILLIAM E. BARRON, *Section Director.*

The floods during the spring of 1913 in the Vicksburg River district consisted of two distinct rises, the second of which was the more important.

The Mississippi River began to rise in this district on January 6 with comparatively low stages prevailing, in which respect this rise was much like the rises of February–March, 1909, and of January–February, 1910. Flood stages were passed at Arkansas City, Ark., 47 feet, on January 30; at Greenville, Miss., 42 feet, on February 2; and at Vicksburg, 45 feet, on February 1. The maximum stages were 50 feet at Arkansas City and 43.7 feet at Greenville on February 11 and 12, and 49 feet at Vicksburg on February 16–18, inclusive. The river fell below flood stage at Arkansas City on February 19, at Greenville on February 18, and at Vicksburg on February 26.

The river continued falling until March 4, when a slow rise set in that gave stages of 35.5 feet at Arkansas City and of 29.2 feet at Greenville on March 12 and 13, and of 38.3 feet at Vicksburg on March 14, after which the river again declined to 31.1 feet at Arkansas City, March 19; 25.1 feet at Greenville, March 20; and 34 feet at Vicksburg, March 22, by which time the Ohio at Cairo, Ill., had been rising for a full week prior to the phenomenal rains of March 23–27 over the Ohio watershed.

The rise in the Vicksburg district was continuous from this time until the stages began to be affected by breaks in the levees. Flood stages were reached at Arkansas City April 5, and at Greenville and Vicksburg April 8. The maximum stages were as follows: Arkansas City 55.1 feet, April 21–25, inclusive; Greenville, 50.4 feet, April 21; Lake Providence, La., 48 feet, on the same date; and Vicksburg, 52.3 feet, April 27 and 28. These stages are three-tenths, two-tenths, and one-tenth of a foot, respectively, less than the record-breaking stages of 1912 at Arkansas City, Greenville, and Lake Providence. At Vicksburg the crest exceeded that of 1912 by two-tenths of a foot, but was two-tenths lower than the high-water mark of 1897. The decline was rapid, and the river passed below flood stage at Arkansas City May 9, at Greenville May 8, and at Vicksburg during May 15.

Frequent rains during January caused a gradual rise in the Yazoo River. At Swan Lake, Tallahatchie County, Miss., it passed above flood stage, 24 feet, on January 16, and reached a maximum stage of 29.3 feet January 30–February 5. As the country drained by the upper Yazoo is flat, and as there were copious rains from time to time, the fall was slow, and by February 26 the water had only receded to 26.8 feet, 2.8 above flood stage. For the next four weeks the stage fluctuated slowly between 27.2 and 26.5 feet. Beginning with the latter reading on March 25, as a result of rains over the watershed on March 20 and 21 and March 23–27, there was another rise to 29.3 feet on April 7 and 8, after which there was a slow fall, the river finally going below flood stage during May 7.

At Greenwood, Leflore County, Miss., on the Yazoo, the highest stage reached on the first rise was 35.6 feet, 2.4 feet below the established flood stage, February 12. The highest stage on the second rise was 33.3 feet, April 16 and 17.

At Yazoo City, Yazoo County, Miss., on the Yazoo, the river passed above flood stage, 25 feet, during February 6, and reached a maximum stage of 28.9 feet, February 19–23, inclusive.

The river fell below flood stage at this point on March 27, over a month after the Mississippi passed below flood stage at Vicksburg. The water had only fallen to a stage of 24.3 feet on April 3, when the second rise set in. Flood stage was reached again on April 5, and the maximum stage, 29.8 feet, occurred May 2–4, inclusive. From this time the river fell and passed below flood stage during May 19.

The Yazoo was above flood stage at Swan Lake continuously for 112 days, and at Yazoo City at or above flood stage a total period of 93 days, although not continuous.

There were five crevasses in the Vicksburg district. One, the break in the levee near Beulah, Bolivar County, Miss., occurred during the first rise, and the others during the second rise.

The most important crevasse of the second rise in the Vicksburg district was the one in the Skipworth levee, about 3½ miles north of Mayersville, Issaquena County, Miss. The water from the Skipworth crevasse passed out along Steels Bayou and Deer Creek and overspread an area of 308 square miles that otherwise would not have suffered in Issaquena, Sharkey, and Washington Counties, and increased the depth of overflow in the lower portion of the delta where the lands were already covered with backwater that had come in between the lower end of the levee system at Eagle Bend, Warren County, and the mouth of the Yazoo at Vicksburg. The total area flooded in the lower Yazoo district from backwater and the Beulah and Skipworth crevasses was 2,235 square miles, as against 2,723 square miles in 1912.

The overflow from Beulah crevasse was 702 square miles as compared with 1,498 square miles in 1912.

Three breaks occurred in the levees along the right bank of the Mississippi in the Vicksburg district. The effect of these breaks was merely to increase the depth and extent of the backwater overflow above the mouths of the White and Arkansas Rivers and Cypress Creek. The total area flooded in the White River district, above the mouth of the White River, was 300 square miles, out of 910 square miles subject to overflow.

On the right bank south of the Arkansas River the whole of this district is protected by levees, with the exception of a gap of 2.9 miles between the levees of the Arkansas and those of the Mississippi, through which Cypress Creek flows into the Mississippi. South of Cypress Creek there is a ridge of comparatively high ground, about 12 miles long, known as Amos Bayou Ridge. Under present conditions water begins to flow over this ridge into the upper Tensas Basin at a stage between 51 and 52 feet on the Arkansas City gage. It is estimated that this discharge, both in 1912 and 1913, reached as much as 200,000 cubic feet per second. The water discharged over this ridge spread southward between the Mississippi River levees and the McGehee and Alexandria line of the St. Louis, Iron Mountain & Southern Railway, following the courses of the Boeuf River and Bayou La Fourche into the Ouachita, and of the Bayou Macon into the Tensas, and thence into the Black and lower Red Rivers. At Arkansas City, Ark., the water from this overflow reached a height equivalent to a stage of 47 feet on the river gage at that point. The total area overflowed along the right bank in this district south of the mouth of the Arkansas River was 1,591 square miles, as compared with 2,270 square miles submerged in 1912.

The public in this district was kept advised of the stages of water to be expected at the several stations, even prior to the issuing of warnings of flood stages. Flood warnings were issued for Arkansas City and Vicksburg on January 18, and for Greenville on January 23, 10 to 14 days in advance, and further advice was furnished during the progress of the rise. The occurrence of the crevasse at Lake Beulah on January 25, before flood stages were reached, presented a problematical condition and at first it was difficult to tell just what the effect would be. The crevasse reduced the flood height but slightly at Arkansas City and Greenville, and prolonged the rise at Vicksburg about three days on account of the return of the crevasse water through the lower Yazoo, and a forecast was made on January 30 covering the situation.

On March 27, as soon as it was seen that the heavy rains of March 23–27 over the Ohio watershed would produce a marked rise in the Mississippi, warnings were issued that flood stages would be reached in this district April 5 to 8. This forecast was verified to the day.

During the early part of the rise the stages forecast were modified as conditions warranted, but it was not believed that the stages of 1912 were probable in this district on account of the lower initial stages. By April 1 the prediction was made that a stage of 54 to 55 feet would be reached at Arkansas City, 48 to 49 feet at Greenville, and 51 to 52 feet at Vicksburg if the levees held. On April 7, owing to the prolonged high stage of 54.7 feet at Cairo, Ill., the forecast was changed to 55.5 to 56 feet at Arkansas City April 17 to 18, 49 to 50 feet at Greenville April 18 to 19, and 52 to 53 feet at Vicksburg April 23 to 24. On April 10 the public was informed that the recent heavy rains over Arkansas would intensify flood conditions, but that the crest would be delayed by crevasses that had occurred in the St. Francis levees. On April 13 the crevasse water from the St. Francis Basin began to return to the main stream at Helena, Ark. The effect that this amount of water would have on the stages below Helena was considered and the following special warning was issued:

The Mississippi will pass 55 feet at Arkansas City, 50 feet at Greenville, and 50.5 feet at Vicksburg by April 17 or 18, after which a slow rise will continue till late in April or early in May, due to the return of the crevasse water from the St. Francis Basin, reaching 56.5 to 57 feet at Arkansas City, 51.5 to 52 feet at Greenville, and 53 to 54 feet at Vicksburg if levees hold.

On April 21, on account of breaks that had occurred in the White River district, which caused an increase in the discharge of water over Amos Bayou Ridge, the estimate was changed to 55.5 to 56 feet at Arkansas City, 51 to 51.5 feet at Greenville, and 52.5 to 53 feet at Vicksburg, providing that there were no further breaks in the levees.

The crevasse in the Skipworth levee occurred that afternoon, and as soon as definite information was received at this office a special forecast was issued that the effect of this crevasse would be to relieve Greenville and Arkansas City and to bring temporary relief to Vicksburg. By the next morning the gage at Lake Providence, La., 12 miles below the crevasse, showed a fall of 1.2 feet, while at Greenville, 52 miles above it, there was a fall of two-tenths of a foot, and at Arkansas City and Vicksburg the rise had been checked, although the river was still rising at Helena, Ark. The fall was continuous after the 21st at Greenville and after the 25th at Arkansas City. By the latter date, as a result of heavy rains in the vicinity and because of the return of the crevasse water, the river was again rising at Vicksburg, and a forecast was issued that a stage of 52.5 feet would be reached. As a result, however, of the crevasse that had occurred in the levee at Lake St. John, La., on the night of April 26, the river was stationary at Vicksburg at a stage of 52.3 feet from the morning of the 27th to the evening of the 28th, and then began to fall slowly.

After the river began to fall the vital question was when the water would pass below flood stage. On May 5 the public was informed that the Mississippi River would pass below flood stage at Arkansas City and Greenville on the 8th or 9th, and at Vicksburg by May 18, barring heavy rains. On May 7 further advice was issued that the Mississippi River would pass below flood stage at Vicksburg by May 15 and that the Yazoo River at Yazoo City would pass below flood stage by May 22 or 23, barring heavy rains. All of these predictions were verified. In fact, it was possible on the 17th to advance the date at Yazoo City to May 20.

During both rises ample warnings were issued for points on the Yazoo River as occasion required.

The warnings and other information relative to the flood issued at this office were given wide distribution. During the critical period the River Bulletin reached a circulation of 1,100 copies. The river conditions were also transmitted by telegraph and telephone without expense to the Government to the levee boards at Greenville, Miss., Tallulah, Lake Providence, and St. Joseph, La., to the Cotton & Merchants Exchange, at Natchez, Miss., and to other interested parties over the district. The board of commissioners of the fifth Louisiana levee district at Tallulah duplicated the river bulletin thus given to them and circulated it to 20 addresses along the line of the St. Louis, Iron Mountain & Southern Railway.

The losses to residents of the districts submerged during the first rise were not great, because the overflow occurred after last year's crops had been nearly gathered and before planting had begun, because the waters came up gradually, as the only levee break, that at

Beulah, occurred before the river had reached a height sufficient to cause a current of great force, and because the people knew they were unprotected and were expecting this overflow.

The largest losses fell on the railroad companies. The Riverside division of the Yazoo & Mississippi Valley Railroad Co. was out of commission between Benoit and Beulah, Miss., from January 26 to February 26, practically the entire roadbed being washed from under the track between those places. The main line of the same railroad sustained a bad washout between Valley Park and Smedes, Miss., and was closed to all traffic from February 19 to 22, inclusive, while service on the branch line from Kelso to Silver City was discontinued on January 31. The main line of the Southern Railway was under water between Holly Ridge and Elizabeth, Miss., from January 29 to March 5. The Napanee branch was also put out of commission for some time, as was also the Richey branch from Delta City to Richey, Miss.

The loss from the second rise was much greater, owing to its later occurrence, to the higher stages, and to the consequent wider extent of the overflow. When the crevasse occurred in the Skipwith levee, couriers were sent in all directions to warn the inhabitants of the territory in advance of the flood waters. The United States Army relief forces that were stationed in readiness at Vicksburg dispatched boats, men, and provisions to the scene, and heroic efforts were put forth to protect human life and care for live stock. It is estimated that there were 10,000 people rendered homeless by this disaster, but it is believed that there were no lives lost, although at first it was reported that there were two. There was much exposure to refugees on account of heavy rains on April 23–24. Buildings on the immediate front of the wave were carried away, as were practically all the bridges over Steels Bayou in Issaquena County. The more important towns and villages affected were Mayersville, Rolling Fork, Grace, Blanton, and Carey. Regular train service on the main line and on the Riverside division of the Yazoo & Mississippi Valley Railroad was discontinued on April 22. The entire line between Vicksburg and Kelso and the east side of the embankment between Kelso and Rolling Fork was already covered with backwater, which acted as a buffer, and the railroad company was able to hold most of their track in place when the crevasse water came, so that they were able to effect an early resumption of service on May 12. Service on the Silver City branch of this railroad, discontinued January 31, was not resumed until June 2.

While some of the lands were damaged by erosion, particularly in the immediate vicinity of the crevasse, where a deep hole covering 102 acres was washed out, many planters believe the overflow a benefit on account of the soil-enriching sediment, which in many places was deposited 2 to 5 inches deep. As the water receded, the planting of cotton was begun on May 15 with favorable prospects.

The most important towns affected by the backwater in Arkansas and Louisiana, were Arkansas City and Lake Village, both in Arkansas. In this territory there were about 10,000 people who were temporarily forced from their homes.

Reports of money losses have been furnished from portions of the flooded districts only, and these vary with the viewpoint and temperament of the persons reporting. Conservative figures based on all these reports, giving the losses exclusive of those to railroads, telegraph and telephone companies, are submitted. The figures given include losses in Vicksburg along the river front, where no permanent levees are maintained, and where the losses to buildings and contents are placed at $15,000, loss by suspension of business, $11,000, and where the warnings were undoubtedly instrumental in saving $200,000 worth of property. Probably $15,000 to $20,000 were expended for local protection.

The cost of high-water protection over the district will amount to hundreds of thousands of dollars, to say nothing of the cost of building and maintaining the levees. Had it not been for the long vigil and the tireless efforts kept up throughout the critical period, the losses would have been multiplied many times. A grave disaster was narrowly averted at Greenville, Miss., as late as April 30.

The loss to prospective crops may hardly be computed with any certainty. If the season is otherwise favorable, the loss may be inconsiderable, while, if unfavorable, it may be even greater than the amount estimated.

COMPARATIVE STAGES IN THE ARKANSAS AND WHITE RIVERS IN CONNECTION WITH THE SPRING FLOODS OF 1912 AND 1913 IN THE MISSISSIPPI RIVER.

By H. F. Alciatore, *Section Director, Little Rock, Ark.*

In 1912 the spring rise in the Mississippi River at Arkansas City, Ark., about 37 miles below the mouth of the Arkansas River, began about March 21. The flood stage was reached eight days later, and the crest stage, 55.4 feet, on April 12.

The volume of water that passed from the Arkansas River into the Mississippi River is indicated by the stages in the Arkansas River at Pine Bluff, Ark., during March and the first week in April. Pine Bluff is 109 miles from the mouth of the river. The Arkansas began to rise on March 23; the stage was then 14.6 feet. There was a continuous rise until April 4. The flood stage was reached on April 3 (25.7 feet), and the crest of the flood occurred on the 4th, the gage reading being 26.2 feet, which was 1.5 feet above the flood level. After the 4th the water receded steadily until the 26th, when the gage read 12.5 feet. As the crest of the flood in the Mississippi did not pass Arkansas City until April 12 (8 days after the Arkansas River flood had passed Pine Bluff) it is evident that the waters from the Arkansas had some bearing on the flood in the Mississippi below Helena, Ark.

As to the amount of water contributed by the White River in 1912 in Arkansas the stages recorded at Clarendon, Ark. (75 miles from the mouth), may be taken as an index. Relatively high stages (27.9 to 28.3 feet) prevailed during the latter half of March. On April 1, the river began to rise. The stage was then 28.6 feet. The flood stage was passed on April 6 (stage, 30.1 feet), and the crest of the flood passed Clarendon on April 14. The stage was 32.6 feet, or 2.6 feet above the flood plane. After that date the river fell steadily at the rate of one or two tenths foot each day. The combined waters of the White and Arkansas Rivers must have had appreciable effect on the flood situation in the Mississippi below Helena, Ark., during the early part of April, 1912.

In 1913, the Arkansas River was not so high during March and April as it was during the same months of 1912. From the 1st to the 26th of March, 1913, the stages at Pine Bluff, Ark., were relatively low, ranging from 8.9 feet on the 21st to 14.4 feet on the 3d. An 8-foot rise occurred between the 26th and 31st, the extreme stages recorded being 11.9 feet and 20 feet, respectively.

The torrential rains that occurred in the lower part of the drainage basin of the Arkansas (from Little Rock, southward) on April 8 and 9 did not cause floods in any part of the river. At Pine Bluff there was a rise of 7.5 feet between the 9th and 14th, the highest stage reported being 20.4 feet on the 14th. This was 4.6 feet below the flood stage. It will be seen that in 1913 the volume of water that passed out of the Arkansas into the Mississippi was relatively small.

As to the White River, the Clarendon, Ark., records show that there was a steady fall during the first 21 days of March, the river reaching a minimum stage of 19.5 feet on the 21st.

On the 22d, the White began to rise. The stage was then 19.8 feet. The flood stage (30 feet) was reached on April 13, and the flood crested on the following day (14th), with a stage of 30.4 feet, which was 0.4 foot above the flood plane. The river remained stationary during the 15th and began to fall on the 16th. It fell slowly, however, the total fall during the last 15 days of the month having been only 1.7 feet.

The spring rise in the Mississippi at Arkansas City in 1913 began about March 20, but the flood stage was not reached until April 6, 17 days later. The crest of this flood occurred April 22, with a maximum stage of 55.1 feet.

It will be noted that prior to the occurrence of the spring flood of 1912 in the Mississippi both the Arkansas and White Rivers had reached higher stages than during the corresponding period preceding the 1913 flood, the high-water stages for those years being 26.2 and 20.4 feet, respectively, at Pine Bluff, on the Arkansas, and 32.6 and 30. 4 feet, respectively, at Clarendon, on the White River; yet the high-water stages recorded at Arkansas City, on the Mississippi, were practically the same—i. e., 55.4 and 55.1 feet, respectively.

NOTES ON THE SPRING FLOOD OF 1913 ON THE ARKANSAS SIDE OF THE MISSISSIPPI RIVER.

In extent and severity the flood of April, 1913, on the Arkansas side of the Mississippi River differed but little from that of 1912. This year the warnings of the Weather Bureau regarding the flood were heeded without question, and as they proved both timely and accurate there was no loss of life.

The first effects of the flood were felt on April 9. The flood waters passing through breaks in the levees near Graves Bayou and Wilson, Ark., covered portions of Mississippi County and spread southward over parts of Poinsett, Crittenden, St. Francis, and Lee Counties. Press dispatches stated that on April 9 several refugees had sought shelter on higher ground at Forrest City, St. Francis County, and in neighboring towns. Railroads west of Bridge Junction, Ark. (opposite Memphis, Tenn.), were practically out of business. Mails from the East were being transferred across the Mississippi River at Helena, Ark. By the 11th the flood had spread over the lower St. Francis Basin, and was making its way toward the Mississippi through the St. Francis River. About 2,000 refugees were camping on high ground near Wilson, Mississippi County. On the 12th, Marked Tree, Poinsett County, was flooded to a depth of 2 to 5 feet. The flood had reached Deckerville and Turrell, Ark. About 1,000 flood sufferers were being cared for at Marianna, Ark. On the 13th the towns of Shawnee Village, Joiner, Bassett, Lepanto, Tyronza, and Deckerville, Ark., were submerged, and the water was higher than in 1912. The St. Francis River at Marked Tree had risen 19 inches in the last 24 hours. About 200 negroes were rescued at Watson. About 2,000 refugees from the eastern portions of Crittenden County were camped at Wynne. Edmonson, Manila, and Clarksdale were under water. A telegram was sent from Osceola, Ark., on April 14 to the governor of Arkansas that the flood waters from the breaks in the levee at Wilson were about 10 feet in depth in the southern part of Mississippi County, and almost reached Osceola; great suffering and destruction were reported in that section. On the 15th the Laconia Circle levee in Desha County, near the mouth of the White River, broke and soon afterwards about 18,000 acres of farming lands were under water.

The flood near Wilson, Mississippi County, was said to be about 2 feet higher than ever known. Marked Tree was still under water. On the 16th backwater from the Laconia Circle break covered the streets of Arkansas City to a depth of several inches, but the levee at that place was intact. Railroad traffic to the south had been suspended, the tracks near Valley and Lake Village being under water. The northeastern part of Chicot County was submerged by the waters flowing through a gap in the levee on Amos Bayou. The road between Luna and Lake Village was flooded. By the 19th the St. Francis section was under water from Hulbert, Crittenden County, westward to Madison, St. Francis County, a distance of about 30 miles. The Rock Island trains were running through water ranging from 3 to 20 inches in

depth. The water from the L'Anguille River was running over the Rock Island Railroad trestle near Palestine, Ark., and was overflowing the "dump" to a depth of 12 to 14 inches. On April 20 the railroad tracks near Forrest City were submerged. At the L'Anguille River crossing trains were running through water for a distance of about 1 mile, the car steps being hidden under the water. At Heth, on the 21st, the railroad tracks were 2 feet under water, and the station platform had floated away. The Rock Island tracks from Round Pond to Proctor were under water, and the Iron Mountain tracks between Felton and Canaan were submerged to a depth of more than 2 feet in some places. The city authorities at Lake Village had issued a call for rations for 1,000 refugees. The St. Francis levee had broken at a point about 3 miles below Whitehall, and the water inside of the levee was only about 3 inches below the water on the river side. Many telegraph and telephone poles along the Rock Island road had been damaged or swept away.

On April 22 the writer left Memphis, Tenn., about 7 a. m. on a Rock Island train bound for Little Rock, Ark. From Hulbert, Ark., a few miles west of the Mississippi River, to Palestine, Ark., a distance of about 50 miles, he observed that the tracks were under water to a depth ranging from a few inches to more than 2 feet over the greater part of the distance. A number of telegraph and telephone poles had been washed away and were floating upon the water on each side of the railroad track. In some places the flood water had almost reached the lower cross-arms on poles that were still standing. Near Heth a high-water mark which had been painted upon a telegraph pole in 1912 was only 5 or 6 inches above the flood waters of 1913 on April 22. Press reports of that date indicated that the bottom lands between the Mississippi River and the L'Anguille River,[1] a distance of 25 to 40 miles, were under water. At Marianna, Ark., on the St. Francis, the river gage at 7 p. m. showed a stage of 47.4 feet, which was about one-half foot below the high-water mark of 1912.

On April 23, 60,000 rations were distributed by the Federal Government among 3,000 refugees at Forrest City. The St. Francis River at Madison had fallen about 2 inches, the stage being 40.7 feet. The L'Anguille River at Palestine had come to a stand. The flood situation was beginning to show improvement everywhere. On the 24th the backwater at Arkansas City had risen about 3 inches, but half of this rise was due to excessive rains. The water was 6 to 8 inches higher than it was in 1912 during the spring flood. At Madison, on St. Francis, the flood had receded about 2 inches. All trains over the Rock Island, except Nos. 45 and 46, were in operation, but all trains were late. By the 28th the water in the streets of Arkansas City had fallen about 4 inches. Near McGehee, Desha County, the flood waters had receded about 3 inches. On that date the territory under water in eastern Arkansas was 6 to 13 miles wide and 30 to 40 miles long.

At the close of April the rivers were falling at all points in the flooded districts, and the situation was improving rapidly. Railroad traffic on lines in eastern Arkansas were running practically on schedule time. Large areas were still submerged, but the flood waters were receding rapidly, and many flood refugees were returning to their homes.

The most expensive features of this flood were the strengthening of the levees, the cleaning and repairing of stores, dwellings, and farm buildings, and the losses incident to the suspension of business throughout the flooded areas. It is impracticable to make a correct estimate of the losses at this time, but it is probable that these will exceed $2.000,000, exclusive of the damages to the railroads.

[1] A tributary of the St. Francis River flowing southward through Poinsett, Cross, and St. Francis Counties.

FLOODS IN THE MISSISSIPPI RIVER BELOW VICKSBURG AND IN THE ATCHAFALAYA RIVER IN APRIL AND MAY, 1913.

By I. M. CLINE, *District Forecaster.*

Stages in the Mississippi River, below Vicksburg and in the Atchafalaya River, on March 31, 1913, were as follows: Natchez, Miss., 39.2; flood stage, 46 feet. Baton Rouge, 29.2; flood stage, 35 feet. Donaldsonville, 22.7; flood stage, 28 feet. New Orleans, 14.5; flood stage, 18 feet. Melville, 35.3; flood stage, 37 feet. Morgan City, 3.7; flood stage, 8 feet. On account of the high water in the Ohio River and its tributaries flood warnings as follows were issued on March 31:

If levees hold, the water now in sight indicates 50.5 to 51.5 feet at Natchez, 40 to 41 feet at Baton Rouge, 32.3 to 33.3 feet at Donaldsonville. and 19.6 to 20.6 feet at New Orleans. between April 20 and 30, 1913.

On account of the changing conditions, such as the fall of rain and the breaking of the levees, it was necessary to modify and alter the warnings from time to time during the continuance of the flood. Warnings were issued on April 4, 9, 10, 21, 23, and 25, and on May 9, 12, and 14, the last warning issued, viz, that of May 14, follows:

The Mississippi River below Vicksburg will fall, but below the mouth of the Red River and in the Atchafalaya the changes will be slight for a few days. The water will fall below the flood stage at Natchez by May 20, and water will probably cease flowing through the Lake St. John crevasse by May 25.

If no breaks had occurred in the levees below Vicksburg, the maximum stage forecast for this district would have been reached. At Natchez a stage of 52.4 feet was reached on April 26 and 27, which is the highest stage ever recorded at that place. The highest stages at other points were as follows: Baton Rouge, 41.3 feet, on May 9; Donaldsonville, 32.7 feet, on May 8 and 9; New Orleans, 20.5 feet, on May 8; Simmesport, 46.9 feet, on May 9; and Melville, 41.7 feet, on April 24.

The water was rising rapidly at Natchez when the levee broke 26 miles above that place on April 27, and but for that break there would have been a further rise of at least 2 feet which would have given the stage forecast. If southerly instead of northerly winds had prevailed stages below the mouth of Red River would have been 1 to 2 feet higher than occurred, because southerly winds would have retarded the discharge and delayed the flood crest until the crevasse water would have returned and united with the flood crest in the main stream. However, the prevailing northerly winds caused the flood crest in the river proper to pass out into the Gulf of Mexico before the crevasse water returned through the Red River.

The following table shows the period during which the water was at or above the flood stage:

Stations.	Period above flood stage.	Total number of days above flood stage.
Natchez	Apr. 11 to May 18	37
Baton Rouge	Apr. 14 to May 25	41
Donaldsonville	Apr. 15 to May 22	37
New Orleans	Apr. 17 to May 24	37
Simmesport	Apr. 17 to May 25	38
Melville	Apr. 9 to May 26	47

Action taken as a result of the warnings.—Warnings were distributed to all post offices in the lower Mississippi Valley regularly, by mail, and when changes were made they were telegraphed to localities affected. When the first warnings were issued on March 31, five weeks before the passage of the flood crest, representatives of all interests likely to be affected by high water took prompt and vigorous measures to combat the coming flood. Levees were raised and weak places strengthened; barges and railroad cars were loaded with materials for making repairs and placed in convenient locations ready to be rushed on short notice to any weak spot which might develop. These precautionary measures proved to be of great value and many threatened breaks in the main levees were stopped by prompt and decisive action, thus preventing more extensive destruction than occurred. Planters raised and strengthened the protection levees around their plantations in anticipation of a possible break in the main levees. This action on the part of the planters enabled several of them to save their plantations from being flooded. A large percentage of stock was driven out of the bottoms to high ground when the warnings were first issued and action was taken to protect household goods and farm products which had been housed.

A special to the Daily Picayune, New Orleans, La., dated Jackson, Miss., April 11, 1913, in speaking of the flood says:

> Because his warnings in previous years have been so accurate, the people residing in the low lands are giving heed promptly to the special flood forecast issued by District Observer Cline, of the Weather Bureau, at New Orleans, La., and are preparing to get live stock to the hills and otherwise safeguard themselves against loss.

When the warning for 54.5 feet was issued for Natchez on April 25, planters, believing that the levees could not be held against such a flood, moved out the remainder of their live stock so that when the crevasse occurred on April 27 nearly all live stock were out of danger and other precautions had been taken, which resulted in the saving of property of great value which otherwise would have been destroyed by the crevasse water.

Crevasses in the New Orleans district.—Only two crevasses in the main levees occurred in this district.

April 25 a crevasse occurred on the left bank of the Atchafalaya River about 8 miles below Melville. No attempt was made to close the crevasse. The water from this crevasse returned to the Atchafalaya River below the end of the levee line. The water from the crevasse overflowed parts of Pointe Coupee and Iberville Parishes.

April 27 a crevasse occurred on the right bank of the Mississippi River at Lake St. John, about 26 miles above Natchez and near the south end of Tensas Parish. The water from this crevasse overflowed Concordia and parts of Tensas, Catahoula, Rapides, and Avoyelles Parishes. Water ceased flowing through the crevasse May 23, and the crevasse water disappeared by June 20.

A break occurred in a private levee opposite Briers, La., on the left bank of the Mississippi River on April 16, flooding about 3,500 acres of farming land with back water.

April 24 a break was barely averted at Remy, La., about 40 miles above New Orleans. The old levee caved rapidly, and for a time it appeared that the new levee could not be gotten into shape to prevent a bad crevasse. By having materials at hand, and by hard work day and night, a crevasse was prevented. (See fig. 13.)

May 1 a cave occurred in the main levee at Poydras Plantation, on the left bank of the Mississippi River, about 10 miles below New Orleans. Prompt action in this case also prevented a serious crevasse.

Area flooded and damage resulting therefrom.—About 1,026,000 acres of land was flooded, of which 255,400 acres is agriculture land. Growing crops were destroyed, and the overflow made it necessary to replant all crops. Cotton, cane, and gardens have been, or will be, replanted. Houses, farm buildings, household effects, public roads and bridges, and railroads suffered damages in varying degrees. No lives were lost as a direct result of the flood, but several lives were lost in accidents indirectly due to the flood. The steamer *Concordia*, while

FIG. 13.—CAVE-IN IN MAIN LEVEE, REMY, LA., AND REENFORCEMENT OF SAND BAGS, APRIL, 1913.

engaged in rescue work on May 1, struck the drawbridge of the New Orleans & Northwestern Railroad across the Tensas River at Clayton, La., and sank in the river, drowning 22 persons, of which number 20 were negroes, mostly women and children.

From the best source of information available up to the present time the damage resulting from the flood is approximately as follows:

Item No. 1:	
(a) Damage to buildings and residences	$7,500
(b) Damage to public roads and bridges	6,250
Item No. 2 includes farm property, and is to be stated under—	
(a) Loss of crops which may or may not have been housed	240,000
(b) Loss of prospective crops (255,400 acres[1])	225,000
(c) Loss of live stock and other movable property	12,000
Item No. 3. Loss due to suspension of business, including wages of employees	75,000
Item No. 4. Money value of property saved by warnings (actually reported)	615,000

The money value of property saved by the warnings actually reported does not represent more than half the savings as a result of the flood warnings because many correspondents do not give amounts.

There have been no extensions of the levee systems since the flood of 1912.

[1] Not all in cultivation; planting had been delayed as a result of flood warnings.

FLOOD IN THE HUDSON RIVER, MARCH 27-28, 1913.

By George T. Todd, *Local Forecaster.*

Flood warnings were issued at 9 a. m. March 26, 1913, for Albany, Troy, and vicinity, and a forecast was made that the water would reach the flood stage (12 feet) that day and probably reach a height of 15 to 16 feet within the next 24 to 36 hours at Albany and a height of 19 to 20 feet at Troy. A cautionary warning was also given the American Locomotive Works and the General Electric Co., at Schenectady.

On March 27, the heavy rains having continued in the upper tributaries, a second flood warning was issued for Albany and Troy, and a forecast was made that the water would reach a height of 20 to 21 feet at Albany and 24 to 25 feet at Troy within the next 24 to 30 hours, and a special forecast was made for the press that the water would reach 19 feet at Albany at about 6 p. m. that night.

The water at Albany reached a height of 16.8 feet at 8 a. m. on the 27th: 19 feet at 6 p. m., and at 1 p. m. March 28th a maximum stage of 22.4 feet was reached.

Except for the flood of February 9, 1857, when the water reached a stage of 22.49 feet, according to the present datum, and there was a strong ice gorge in the Hudson River just below this city, this is the highest stage of which there is any record.

Before noon of the 27th the rising water had put out the fire in the heaters in the United States post-office building in which the Weather Bureau is quartered and the electric current for lights and power was shut off about the same time. The office force were compelled to work in the rooms without any heat till Monday morning, March 30.

So far as known, there was only one human life lost during this flood.

The greatest loss from the flood was occasioned by persons who, though doing business near the river, were unable to believe that their property would be flooded. When warned they would say that the firm had been in business in that section or store for 50, 75, or 100 years and that their building had never been flooded before except when there was an ice gorge; that they thought this office must be mistaken, and that they did not believe it was possible for the water to reach a height of 21 feet or more without the help of an ice gorge. There was also a considerable loss through the scarcity of help and the comparatively short time allowed for the moving of such a large amount of goods.

FLOODS IN NEW YORK.

Mr. Robert E. Horton, consulting hydraulic engineer, Albany, N. Y., in the Engineering Record of April 5, 1913, describes the floods in the State elsewhere than in the Hudson watershed. He says:

Heavy rains which were general throughout the State on March 25, 26, and 27 caused floods of unusual magnitude on nearly all streams in New York. Streams in eastern New York reached their highest stages early on the morning of March 28. Wherever reliable reports can be obtained the volume of discharge at

the flood crest was very much greater than for any preceding floods for which there are authentic records. The flood was due to rainfall alone, coming at a time when the rivers were already swollen, the ground saturated, and lakes and marshes full. The height of water was not accentuated either by ice gorges or by the failure of dams or reservoirs, yet the stages reached in most places were higher than any hitherto known.

The average rainfall throughout eastern New York from the morning of March 24 to the morning of March 28 was about 4 inches. The amount varied in different localities from 2 and 2.2 inches at Albany to 5 inches or more in the southern Adirondack slope. The discharge of the Hudson River increased in 48 hours, between the morning of March 26 and the morning of March 28, from 40,000 to 120,000 second-feet. This was at Mechanicsville, 18 miles above Albany, where the drainage area is 4,500 square miles. The maximum discharge of the Mohawk River, which is the chief tributary to the Hudson, is not yet known, but may be safely estimated at from 75,000 to 100,000 second-feet, so that the combined flow of the Hudson and Mohawk Rivers past Albany was approximately equal in volume to the Niagara River.

The greatest flood hitherto recorded on the Hudson River, in 1857, reached a volume of 70,000 second-feet at Mechanicsville, and a stage of 21.16 feet above mean tide at Albany. The maximum stage at Albany in the present flood was 22.4 feet above mean tide at 1 p. m. March 28. Large areas were overflowed in the most populous and built-up districts at Albany, Troy, Watervliet, and Green Island on the Hudson River and at Schenectady, Fonda, Amsterdam, St. Johnsville, and other towns along the Mohawk River. The entire Mohawk River flats from Little Falls to Schenectady, a distance of 60 miles, were submerged to the greatest depth ever known.

The present Erie Canal, the four-track system of the New York Central Railroad, trunk telephone and telegraph lines, an important State highway, the West Shore Railroad, and for a large portion of the distance a double-track trolley system traverse this valley. In addition there are eight locks and movable dams recently completed for the canalization of the Mohawk River. Traffic of all kinds was interrupted and considerable damage was done locally to railroad roadbeds and to the present Erie Canal. All of the new Barge Canal locks in this district were completely submerged, but so far as can be learned the Barge Canal structures here and elsewhere in the State suffered but little damage. The gates of one of the movable dams at Fonda were bent and injured. This was probably due to drift coming down against the gates, making it impossible to raise them.

In the cities and towns great inconvenience was caused to people located within the flooded districts. Timely warnings, however, were issued by the local forecaster, Mr. George T. Todd, of the Albany station. Many persons heeded these warnings and avoided injury to their property as much as possible. Others refused to believe that a flood greater than that of 1857 was coming upon them. They did not clear their cellars or move their perishable goods, and suffered serious consequences. In the Hudson River there are many water-power dams, some of them constructed of timber or cribwork and a number very old. All of these withstood the flood in safety.

Many bridges were destroyed, including a highway bridge at Glens Falls across the Hudson River, the Erie Canal bridge across the Hudson River at Northumberland, the highway bridge across the Hudson River at Amsterdam, the highway bridge across the Mohawk River at Herkimer, and the highway bridge across West Canada Creek at Trenton Falls.

Damage to the banks of the Erie Canal in different parts of the State is reported by the department of public works as follows: About 100 feet of canal bank washed out at a point opposite the cemetery road between Albany and Watervliet; a considerable length of canal bank washed out west of Schenectady, near Patersonville; about 50 feet of canal bank washed out between Locks 35 and 36, just east of Little Falls; about 150 feet of canal bank washed out on the Cayuga and Seneca Canal at Seneca Falls. The last-mentioned washout caused the shutting down of various mills in Seneca Falls.

A number of Erie Canal bridges were injured or destroyed and many of the smaller canal aqueducts were damaged. The flood on the Mohawk River reached a stage 3 feet above the bottom of the trunk of the main Erie Canal Aqueduct crossing the Mohawk River at Crescent. This is a very old stone aqueduct, but in spite of the high stage and large volume of water it withstood the flood in safety.

Contractors on the Barge Canal in the Hudson and Mohawk Rivers had their concrete and structural work mostly completed and their plants removed from the river some time ago. There were many dredges in these rivers, but with one exception all kept their anchorages. One dredge, which broke loose from its moorings drifted downstream about 1 mile and stranded upon an island. Contractors lost considerable property in the way of pipe and other equipment, but the loss is very much less than would have been the case had the flood occurred a year or two sooner.

In view of the large industrial developments in the valleys of the Mohawk and Hudson Rivers, and in view of the sudden rise and unprecedented height reached by this flood, it is extremely remarkable that the amount of damage done was not very much greater. The fact that there were so few great individual calamities is also notable. The damage, great as it is, was very widely distributed, and is made up of an enormous number of relatively small items. It is impossible to estimate its amount with any degree of certainty.

The Oswego River, according to the best reports obtainable, did not suffer so severe a flood as was experienced elsewhere in the State. This was undoubtedly due to the great natural storage furnished by the

finger lakes in central New York, which are tributary to the Oswego River through the Oneida and Seneca Rivers.

The Genesee River rose to a greater height than has hitherto been known, flooding a large district of the city of Rochester and causing extensive damage. The greatest floods of the Genesee River in past years were in 1865 and in 1894. The discharge at Rochester during these floods is estimated at about 40,000 second-feet from a drainage area of 2,365 square miles. The discharge in the present flood can not yet be estimated. It is probable that the extensive damage and high stage reached in Rochester are due in part to constriction of the channel, as the Genesee River flows through the heart of the city, and, in fact, passes underneath the main business street in the heart of the commercial district, where the river is covered over by buildings for a considerable distance. Just above this street is located the Erie Canal Aqueduct, the obstruction of which has hitherto been a prolific source of trouble in causing floods.

SUPPLEMENTAL NOTE ON FREQUENCY OF RECURRENCE OF HUDSON RIVER FLOODS.

By ROBERT E. HORTON, *Consulting Hydraulic Engineer.*

The question of the frequency with which a flood of a given magnitude may be expected to occur is probably of fully as great importance as the physical data relative to the flood itself; yet this matter of flood frequency seems to have been generally overlooked. The enthusiastic advocate of storage for flood control or the man whose property has recently suffered damage from a severe flood is not apt to stop to think that the particular flood under consideration may not occur again in 100 years. The man who has been injured knows that the flood has occurred and apparently can occur again, and he naturally wants a remedy applied at once, if possible. The question of average frequency of recurrence of great floods is, however, of much importance. The question arises: Is the expenditure of large sums of money for the construction of storage reservoirs justifiable to control floods which will occur on an average not oftener than once in say 100 years? There are few instances in which any reliable deductions as to the probable frequency of recurrence of great floods can be made. Since floods are generally due to excessive rains, the problem may be attacked by studying the frequency of recurrence of great storms. This is a valuable aid to the study for the reason that records of rainfall are available which are much more complete and of very much longer duration than records of the flood stages of streams. There is great lack of consistency in the practice of engineers in regard to provision for floods in engineering structures. On a given stream we will find one structure with flood provision adequate to withstand floods of the greatest intensity which will occur on an average once in 100 years, other structures, which are liable to injury by flood as often as once in 10, 20, or 30 years on an average.

The late George W. Rafter suggested to the writer in 1896 the possibility of the application of the theory of probabilities to the analysis of flood records, rainfall records, and other hydrological data. The object in view was the development of a consistent method for the design of engineering structures dependent for their success on hydrological phenomena of more or less periodic occurrence. Following this suggestion, the writer has developed and applied methods of analysis of such data by the theory of probabilities, utilizing in some instances the ordinary Gaussian law and in some instances developing special probability curves, formulas, and diagrams similar to those here given for the Hudson River.[1] The above statement is made in order to give Mr. Rafter credit for the first suggestion of the method in its broadest sense and also because the method has been used by the writer for more than 10 years

[1] Not reproduced.

in connection with the design of structures aggregating several millions of dollars in cost, and the further application of this method seems to be justified by actual experience.

It is certainly in the line of making the best possible use of the available information. This method has been applied to flood discharges of the Hudson River at Mechanicsville. Table 1 shows the date in each year on which the maximum flood discharge has occurred at Mechanicsville during the past 26 years. The quantity of discharge given is the greatest average for one day. The absolute maximum for less than one day's time was somewhat greater in each instance. In applying this method to the Hudson River the data have been arranged in the order of magnitude shown in column 2 of Table 2. Column 3 shows the number of observed floods equal to or greater than a given magnitude. Column 4 contains the reciprocals of the numbers in column 3 and shows the probable average interval of recurrence in years of floods equal to or greater than the corresponding quantities in column 2. The data from column 2 have been plotted as ordinates and those from column 3 as abscissas on the accompanying diagram.[1] Logarithmic cross-section paper was used for plotting, and the ordinates were adjusted by the use of an addition constant, so as to reduce the line of plotted points substantially to a straight line. A straight line drawn through the plotted points represents empirically the law of relation between magnitude and frequency of recurrence of floods within the range of observation. By the extension of this line or by deduction of the corresponding formula the probable frequency of recurrence of floods greater than any hitherto observed can be inferred. In making such inferences it must of necessity be assumed that the same laws govern the frequency of recurrence of greater floods. Two formulas for this special probability curve are given on the diagram. One formula shows the magnitude "Q" of floods which will probably be equaled or exceeded once in "I" years on an average; the other shows the average interval of years "I" at which the flood of a given magnitude "Q" will probably be equaled or exceeded.

$$I=\left(\frac{Q+50,000}{80,000}\right)^{7.14}$$

$$Q=80,000\ I^{0.14}-50,000$$

For example: In order to determine the probable average interval of recurrence of a flood as great as that of March, 1913, we have

$$I=\left(\frac{113,500+50,000}{80,000}\right)^{7\ 14}$$

Solving by logarithms, we get

$$I=165 \text{ years.}$$

Here we have a flood magnitude which will apparently only be equaled or exceeded once in 165 years on an average, but which has actually been observed once in a period of 26 years. There are a number of ways in which data similar to that here given may be plotted to deduce a special probability curve. It may be plotted either as a direct or as an inverse probability curve and either on logarithmic, semilogarithmic, or plain paper. It is often desirable to plot the data by two or more methods in order to fix the best position of the curve. This was done in the present instance.

If the occurrence of floods of different magnitudes was a matter of pure chance, then their relative frequency of recurrence could be determined by the ordinary Gauissian law of error. In cases where the available records are of short duration the deriviation of a special probability curve by the method which has been given is impracticable. In such cases the Gaussian law of error properly applied is a valuable aid in the interpretation of the data. As a rule, however, the writer has found that large floods occur with much greater frequency than the Gaussian law would indicate. This is accounted for in part by the fact that in the derivation of the

[1] Not reproduced.

Gaussian law, plus and minus departures from the mean of the observed phenomena, are assumed to be equally probable. Obviously a flood can not very well be as much as 100 per cent smaller than the mean flood, while it may exceed the mean flood by 200 or 300 per cent or even more. It follows that in a given record there are usually more floods below the mean than there are above. The average maximum yearly discharge of the Hudson River at Mechanicsville for the past 26 years has been 41,876 second feet. In 17 out of the 26 years the maximum discharge was less than this, and it was greater in only 9 years. As a result of this condition, the Gaussian law indicates departures above the mean having considerably less than the observed or actual frequency. This error may be partly eliminated in applying the Gaussian law by considering only departures above the mean; but even so, the Gaussian law indicates a probable flood interval of recurrence for a flood on Hudson River as great as that of 1913 of 667 years, as compared with an average interval of 165 years deduced from a special probability curve.

Without going into detail, the writer would say that the analysis of many of the longest rainfall and flood records throughout the world points strongly to the conclusion, tentatively at least, that floods of very great intensity actually occur with considerably more frequency than the laws of occurrence of floods of ordinary intensity would indicate should be the case. To what this is due can not at present be stated. The suggestion is inevitable, however, that conditions come into play in the production of heavy rainfalls which are not ordinarily in operation. The ultimate causes of rainfall are much less fully understood to-day than was supposed to be the case 10 or 20 years ago. Recent investigations of molecular physics, condensation on electrons and ions, electrification, surface tension, and the possibility of supersaturation at high altitudes suggest a number of ways in which excessive rainfalls may be produced at rare intervals from causes which are not ordinarily in operation. Owing to this apparent tendency for abnormally great floods and rainfalls to occur with greater frequency than the laws of occurrence of lesser floods would indicate should be the case, the writer is of the opinion that floods of this magnitude in the Hudson River may probably be expected to recur at average intervals less than 165 years. That a flood as great as this, exceeding the average flood for 26 years by 170 per cent and exceeding the greatest flood hitherto recorded by 62 per cent, will be of rare occurrence seems obvious.

TABLE 1.—*Maximum discharge of Hudson River at Mechanicsville, N. Y., for 26 years.*

[Drainage area 4,500 square miles. Maximum given is greatest average flow for 24 hours.]

Date.	Discharge (cubic feet per second).	Cubic feet per second per square mile.	Date.	Discharge (cubic feet per second).	Cubic feet per second per square mile.
1	2	3	1	2	3
Apr. 7, 1888	31,130	6.93	Mar. 25, 1903	56,283	12.5
May 1, 1889	22,400	4.99	Apr. 11, 1904	36,305	8.07
May 27, 1890	24,300	5.40	Apr. 1, 1905	48,877	10.9
Apr. 20, 1891	33,120	7.14	Apr. 6, 1906	40,279	8.95
Apr. 25, 1892	30,110	6.69	Apr. 1, 1907	36,672	8.15
Apr. 15, 1893	25,460	5.66	Apr. 28, 1908	34,335	7.63
Mar. 24, 1894	25,560	5.68	Apr. 16, 1909	46,299	10.3
Apr. 10, 1895	49,630	11.0	Apr. 3, 1910	37,809	8.41
Apr. 19, 1896	67,000	14.9	May 3, 1911	26,241	5.83
Dec. 16, 1897	35,700	7.93	Apr. 8, 1912	47,275	10.5
Mar. 14, 1898	39,231	8.72	Mar. 28, 1913	113,510	25.2
Apr. 26, 1899	41,475	9.22			
Apr. 23, 1900	43,546	9.68	Average	41,875	....
Apr. 24, 1901	54,862	12.2	Spring, 1869	70,000	15.6
Mar. 3, 1902	41,362	9.19			

TABLE 2.—*Floods of Hudson River at Mechanicsville, N. Y., arranged in order of magnitude, with average interval of recurrence and departures from the mean for each flood.*

Number.	Discharge (cubic feet per second).	Average interval (years).	Departure from the mean. Excess.	Departure from the mean. Deficiency.	Departures for floods exceeding 41,876 cubic feet-seconds. Excess.	Departures for floods exceeding 41,876 cubic feet-seconds. Deficiency.
1	2	3	4	5	6	7
1	22,400	1.00		19,474		
2	24,300	1.04		17,574		
3	25,460	1.09		16,414		
4	25,560	1.13		16,314		
5	26,241	1.18		15,633		
6	30,110	1.24		11,764		
7	31,130	1.30		10,744		
8	33,120	1.37		8,754		
9	34,335	1.45		7,539		
10	35,700	1.53		6,174		
11	36,305	1.62		5,569		
12	36,672	1.73		5,202		
13	37,809	1.86		4,065		
14	39,231	2.00		2,643		
15	40,279	2.17		1,595		
16	41,362	2.36		512		
17	41,475	2.60		400		
18	43,546	2.89	1,672			15,041
19	46,299	3.25	4,425			11,288
20	47,275	3.71	5,401			11,312
21	48,877	4.33	7,003			9,710
22	49,630	5.20	7,756			8,957
23	54,862	6.50	12,988			3,725
24	56,283	8.67	14,409			2,304
25	67,000	13.00	25,126		8,413	
26	113,510	26.00	71,636		54,923	
Mean	41,876					

Flood record rainfall at Conservation Commission stations in New York State.

Date.	Altmar.	Boonville.	Faust.	Hooker.	Ithaca.	Nehasane.	Knowlhurst.	Old Forge.	Little John.	Redfield.	Smartville.	Linden.	Words Cr.	Orangeville.	Varysburg.	Potsdam.	Wells.	Fox Bridge.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1913.																		
Mar. 22												0.16		0.35	0.60			
23		0	0	0.75	0.06	0	0	0.41	0.70	0.50	0.50	.28	0.25	1.41	1.94	0.19	0.38	0
24	0.25	0.15	0.45	.70	.18	0.77	.18	1.35	.99	1.03	.97	1.68	1.03	.83	.40	.85	2.00	0.41
25	1.28	1.10	.67	.61	1.41	.99	2.00	.70	.58	1.30	.60	.42	.91	1.17	1.20	.70	1.05	1.10
26	.61	.36	1.31	.25	.99	.58	1.25	1.70	1.24	0	1.18	1.13	2.20	.42	.23	.90	1.79	.82
27	1.17	1.52	.26	1.30	.24	1.29	1.55	.06	0	.06	.11	T.	.02			.50		1.00
28	.21	0	0	0	T.	.08	0											0
29	0																	
30																		
22–28	3.52	3.13	2.69	3.61	2.88	3.71	4.98	4.22	3.51	2.89	3.36	3.67	4.41	4.18	4.47	3.14	5.22	3.33

FLOODS IN THE CONNECTICUT VALLEY AND IN VERMONT, MARCH 25–31, 1913.

By W. W. NEIFERT, *Local Forecaster, Hartford, Conn.*

The mild rainy weather of March 20–22 reduced to water the small amount of snow and ice remaining in the woods and mountains of the extreme upper watershed. Under usual seasonal conditions this small quantity of snow and ice would not have resulted in great floods; but the fact that considerable frost yet remained in the ground and the thoroughly saturated condition of the soil, made conditions favorable for a rapid run-off. The small streams soon filled to overflowing, breaking up the ice and causing gorges. These conditions being augmented two days later by heavy rains, a sharp rise in the larger streams quickly followed. The ice gorges and overflowing streams caused a moderate amount of damage in the small streams at Montpelier, Barre, Lancaster, Littleton, Lyndonville, and St. Johnsbury, Vt. Moreover, by reason of the fact that the initial stages of the larger streams were relatively high, a large volume of water was soon sweeping down the upper Connecticut with irrsistible force, inundating thousands of acres of land, and doing damage of such extent that it can not be accurately estimated in a monetary sense. The flood was due chiefly to heavy rain falling on thoroughly saturated soil, which was only partly free from frost, and consequently many of the washouts and landslides occurred on frost formations. The absence of the usual spring covering of snow with its considerable water content, surely minimized the losses which occurred. However, the flood over the upper valley was the greatest since 1869, while in the lower valley it brought the highest water since 1896.

On the headwaters of the Connecticut, as at Wells River, Vt., the river was at a relatively high stage on the morning of the 25th. It rose 3 feet, viz, from 27 to 30 feet during that day, and this rise, in connection with the rains which had fallen over the watershed, was the first intimation of a flood throughout the course of the river in Massachusetts and Connecticut.

At White River Junction, 46 miles below Wells River, the Connecticut River at 8 a. m. March 25, stood at 14.6 feet, and at 4 p. m. of that date it had risen to 20.3 feet; it reached a maximum height of 30 feet at 9 p. m. of the 27th, thus overtopping all previous high records back to 1869. While no precise measurements of the stages of the river at White River Junction during the memorable floods of 1869 and 1862 are at hand, a reliable witness of both floods is authority for the statement that the 1913 flood exceeded both of the earlier floods.

The breaking of a big log boom at Sharon, Vt. (on White River), by which 2,500,000 to 3,000,000 feet of logs were set adrift, was the cause of the loss of the highway bridge at White River Junction, and the placing in jeopardy of the Boston & Maine Railway bridge across the White River.

At Holyoke, Mass., the river was at a stage of 5.9 feet at 8 a. m. of the 26th, 9.2 at the corresponding hour of the 27th, and crested at a stage of 12 feet at 7 p. m. of the 28th, continuing at that stage practically all of that night. The high water not only flooded many of the cellars in the lower portions of the city, but also caused the suspension of power plants and manufacturing concerns during the continuance of the flood.

At Springfield, Mass., the highest stage reached was 20.8 feet, or nearly 2 feet below high water of 1854. At this stage cellars were flooded, streets and railways and low-lying truck farms were submerged, and in some cases persons were compelled to move to the upper stories of their houses in order to escape the water. The same experience was had at Thompsonville and Windsor Locks, points farther down river.

At Hartford persons along the river front began moving their belongings to places of safety as soon as a flood stage was forecast; when 20 feet of water on the Hartford gage was assured an immense amount of movable property was transferred to higher levels; nevertheless, much damage to buildings and other immovable property resulted.

Below is a comparative table of 1913 maximum stages as compared with earlier records.

Comparative table of flood stages.

Station.	Highest stage on record.	Year.	Highest stage 1913.
	Feet.		*Feet.*
Wells River, Vt.	35.0	1909	36.0
White River Junction, Vt.	26.3	1895	30.0
White River Junction (White River)	25.7	1895	29.4
Bellows Falls, Vt.	19.4	1895	19.0
Holyoke, Mass.	12.7	1869	12.0
Springfield, Mass.	22.2	1854	20.8
Hartford, Conn.	[1] 29.8	1854	26.3

[1] The 1869 flood made a mark of 26.7 feet.

The loss to railroads in connection with this flood is estimated at $200,000. As there are many things that can not be reduced to dollars and cents which are really of considerable damage to railroad and other interests, it is impossible to furnish exact data as to losses. In Hartford the loss ranges from $50 in some cases to $1,000 in others, and likewise in the various towns the losses range from $100 in one town to $2,000 in others.

NOTE.—Loss of bridge at White River Junction amounts to $37,000; value of logs of Sharon boom actually lost, $10,000; loss to Hartford tobacco firms, $2,000; value of freight house at Middletown, $7,000; loss to steamboat company at Hartford, $2,500.

The fatalities were: A man drowned at Highgate Springs, Vt.; a boy drowned while pleasure boating at Hartford; and at East Putney, Vt., a railway employee was drowned when a freight train slid into the river.

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